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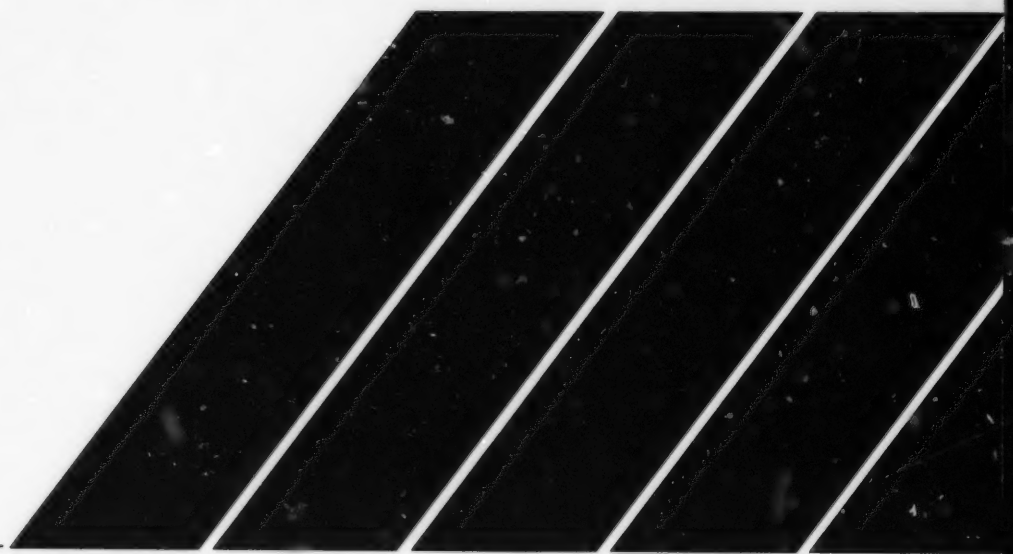
REMOTE RESIDENTIAL PHOTOVOLTAIC SYSTEMS IN BRITISH COLUMBIA: A STUDY



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REMOTE RESIDENTIAL PHOTOVOLTAIC SYSTEMS IN BRITISH COLUMBIA: A STUDY

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EXECUTIVE SUMMARY

There is a growing popularity of photovoltaic power systems for remote residential applications. As opposed to industrial/commercial applications, there is no good source of data on the extent or effectiveness of PV technology's penetration into the remote residential area, i.e., performance, costs, maintenance, problems, and benefits.

The author was contracted under EMR Canada's Enerdemo program to conduct a survey of existing residential PV users to collect such data, including a monitoring phase, and to analyze, document, and report on these systems.

A comprehensive search was carried out to locate PV systems within British Columbia. Approximately 200 questionnaire forms with subjective emphasis were mailed. The 80 returned surveys ranged from:

- 5 watt to 875 watt arrays
- as little as $200 to over $14,000 system cost

The survey results showed an overwhelming majority of present users expressing overall satisfaction with the technology's contribution to their lifestyle, in a market-driven economy.
Fifty-seven respondents used one or more of the following words/phrases when asked "From your experience, please comment on the performance & usefulness of PV": excellent; cost-effective; no maintenance; quiet; non-polluting; wonderful; trouble-free; will buy more; beats operating "noisy, smelly, high-maintenance" gas & diesel gensets.
Fourteen specifically mentioned low winter power as a problem. Only 8 to 10 said the technology is expensive in relation to its output generally.
Three who also use windpower and one who also uses waterpower preferred PV for its low maintenance; two of these mentioned towers as stumbling blocks.

No major problems were encountered in setting-up and operating a PV system by do-it-yourselfers. Moreover, it is the technology's simplicity, reliability, and universal applicability that is the key to its success.

It was noted that load profile estimation and system sizing calculations are difficult because control over the users' behaviour with respect to the power system is nearly non-existent when compared to industrial settings.

Within the Project's budget, low-level monitoring (amphour data only) of multiple sites was considered a useful and interesting alternative to multi-channel data loggers at only 1 or 2 sites. Therefore, ten of these systems were selected for monitoring as being representative based on size, design characteristics, and geographical location; a detailed technical inspection and photographing was carried-out.

Much opportunity still remains for cost-performance optimization, mainly due to large seasonal variations in Canadian insolation. Some relatively easily implemented techniques are identified, but others will depend on users' knowledge of energy flows, electricity, storage battery behaviour, and willingness to accept some lifestyle adaptations.

A frequent problem area is the battery storage component. Unfortunately, it is not only woefully misunderstood, but considerable "mythology" exists which is difficult to counter.

Some comparisons are made of PV to other remote power technologies.

Remote residential photovoltaic systems should continue to gain acceptance and more widespread use, especially as module costs drop and more efficient loads (appliances) become practical. Food refrigeration/freezing play an important role in the perceived usefulness of a remote power system; while super-efficient units are now expensive, good reasons are given for future cost reductions.

Résumé

Depuis quelques années, la popularité de la technologie photovoltaïque auprès des habitants de régions éloignées a considérablement augmenté. Contrairement au domaine industriel ou commercial assez bien documenté sur la question, il n'y a pas, pour le domaine résidentiel, beaucoup de données sur l'importance ou l'efficacité des systèmes photovoltaïques (PV) tels le fonctionnement, les coûts, l'entretien ainsi que les problèmes et avantages de ces systèmes. L'auteur de ce document, subventionné par le programme Enerdémo du Ministère de l'énergie, des mines et des ressources, a donc effectué un sondage auprès d'utilisateurs de la technologie PV en Colombie-Britannique et a fait le suivi d'installations PV pour analyser, documenter et faire un compte-rendu des systèmes.

Une recherche a été effectuée afin de découvrir où sont situés les systèmes PV en Colombie-Britannique. Par la suite, approximativement 200 questionnaires ont été envoyés. Les 80 questionnaires remplis et retournés portaient sur un éventail de systèmes compris entre 5 watts et 850 watts et comportaient des coûts variant de 200 $ à plus de 14 000 $.

Les résultats du sondage ont démontré qu'un nombre impressionnant d'utilisateurs étaient satisfaits de la performance de cette technologie tant sur le plan économique que pratique.

À la question "Selon votre expérience, pouvez-vous ajouter un commentaire sur le fonctionnement et l'utilité de la technologie PV?", cinquante-sept utilisateurs ont indiqué un ou plusieurs des choix suivants : excellent; bon rapport coût-efficacité; aucun entretien; silencieux; non-polluant; merveilleux; sans trouble; intention de s'en procurer; mieux que les systèmes à essence ou diesel qui sont bruyants et qui requièrent un entretien continu.

Quatorze personnes ont mentionné des problèmes relatifs à l'hiver et à la diminution de l'énergie solaire à cette période de l'année. Seulement 8 à 10 personnes étaient d'avis qu'en général la technologie était un moyen dispendieux de produire de l'énergie.

Trois utilisateurs d'énergie éolienne et un utilisateur d'énergie hydraulique ont déclaré qu'ils préféraient la technologie PV parce qu'elle exige peu d'entretien; deux d'entre eux ont mentionné des difficultés liées aux éoliennes.

Aucun problème majeur n'a été déclaré en ce qui concerne l'installation et l'opération des systèmes PV. De plus, c'est la simplicité, la fiabilité et les applications multiples de cette technologie qui sont la clé de son succès.

Il est à noter que l'estimation du profil de charge et les calculs de la taille des systèmes PV sont difficiles à établir. En effet, les données sur les systèmes PV conçus pour un usage domestique sont pratiquement inexistantes comparativement à l'information qui existe dans le cas des systèmes conçus pour usage commercial.

Dans le cadre budgétaire du projet, un simple suivi de plusieurs sites (données d'ampérage/heure seulement) a été considéré comme une solution avantageuse par rapport à un suivi informatisé de seulement 1 ou 2 sites. En conséquence, 10 de ces systèmes ont été choisis pour une surveillance contrôlée basée sur leur représentativité par rapport à la taille, les caractéristiques de conception et la situation géographique. Une inspection technique a été réalisée et des photos ont été prises de chacun des systèmes à l'étude.

L'optimisation du coût-performance des systèmes PV est encore difficile à établir à cause des grandes variations saisonnières d'ensoleillement au Canada. Quelques aspects de l'utilisation de la technologie PV sont reconnus. D'autres aspects sont moins évidents : posséder des notions de base en électricité et bien comprendre les phénomènes de la charge de batteries ou encore avoir la volonté d'accepter des changement à son mode de vie.

Le stockage de l'énergie dans des batteries est souvent cause de problèmes. Malheureusement, il s'agit d'un domaine souvent mal compris où existent de nombreux mythes qui demeurent difficiles à surmonter.

En conclusion, l'utilisation des systèmes photovoltaïques pour habitations éloignées est populaire et la tendance devra continuer à augmenter à mesure que les coûts des systèmes PV diminueront et que des appareils électro-ménagers plus efficaces apparaîtront sur le marché.

TABLE OF CONTENTS

Acknowledgements
Executive Summary
Résumé

1.0 Introduction 1

2.0 Objectives 2

3.0 Project Description 3

4.0 Monitoring 6

5.0 Discussion of Survey and Site Visit Findings 9
- Modules
- Mounting structures
- Regulators
- System voltage
- Energy storage
- Inverters
- Loads
- Meters and wiring
- Back-up power
- Performance: owners' comments

6.0 Observations 15
- Load reduction and conservation
- Load matching
- Problem areas: storage, inverters, refrigeration 19
- Comparisons of remote home power technologies: PV, small hydro, wind thermoelectric 22

7.0 Conclusions 26

8.0 Recommendations 27

Appendices

A. Ten studied sites: locations, detailed data, monitoring results
B. Survey questionnaire, amphour meter specs, monitoring forms
C. Accompanying text for 35 mm slides of the 10 studied sites

INTRODUCTION

Remote, small-scale (less than 100 KWH/month) residential electric power systems have a unique set of economic criteria. Load reduction, especially where alternative sources are suitable, and conservation are the key elements.

For example, in analysing the power consumption of typical grid-connected household loads, it can be estimated that 10% of the energy can do 50% of the jobs because certain ones are so much more energy intensive than others. Moreover, many of these high-consumption tasks (water heating, cooking, clothes drying) can be served nearly as well by non-electric sources such as propane and wood.

Remote homeowners are willing to pay $0.50 to $2.00/KWH (versus 5 to 6 cents/KWH for grid power) for this seemingly small portion of an average home's electrical use because a myriad of low-energy tasks, not possible without electric power, can be accomplished. For example:

- electric motor driven loads - automatic washer, vacuum cleaner, blender, sewing machine, pumps, power tools.
- electronic equipment - sound system, TV, VCR, computer, radiotelephone.
- electric lighting - incandescent, fluorescent.

Solar electric (photovoltaic) systems with battery storage can provide this power 24 hours/day at a reasonable capital cost, the modules having an expected 20 to 30 year life with nearly zero maintenance.

Aesthetic considerations, although more difficult to quantify, are definitely part of the decision to purchase PV technology:

- no noise or pollution.
- no consumption of fossil fuels (besides their cost).
- directly beneficial use of renewable solar energy.
- energy independence.

OBJECTIVES

There is a growing popularity of remote residential photovoltaic (PV) systems. As opposed to industrial/commercial applications (telecommunications, weather & hydrologic stations, cathodic pipeline protection), there is no good source of data on the extent or effectiveness of PV technology's penetration into remote residential power generation, e.g., performance, costs, maintenance, problems, and benefits.

This project conducted a survey of existing residential (not industrial/commercial) users in British Columbia to collect such data, including a monitoring phase, and to analyze, document, and report on these systems. This information should be of use to government, potential PV users, PV sales companies, and others involved in the development of PV systems.

An Information & Technology Transfer (ITT) phase will disseminate this information to potential users.

PROJECT DESCRIPTION

Inventory:

A comprehensive search was carried out from October 1987 to January1988, to locate PV system owners within British Columbia:

- Twenty PV sales companies were contacted both in and nearby B.C. (some resistance was encountered in disclosing customer's names).
- Seven B.C. aquaculture organizations were contacted (the proponent also attended aquaculture trade shows).
- Several B.C. Ministry of Agriculture & Fisheries personnel were contacted and a notice was placed in their Southern Interior Newsletter.
- Telephone inquiry to regional alternative energy activists, who also mentioned like-minded activists elsewhere.
- A grass-roots PV newsletter (US based) provided information on some B.C. users.

Survey:

A one-page questionnaire form (see Appendix B) with covering letter was composed and mailed to each identified owner/user. Note that some emphasis was placed on subjective responses. A spare form was included in case the addressee knew of neighbors/friends using PV. A stamped and addressed return envelope was provided.

In a few instances, batches of forms were sent to PV activists for local distribution, and in one instance to a hesitant PV sales company for anonymous return.

A total of approximately 200 questionnaires (not counting spares) were mailed-out.

Response:

A total of 80 completed questionnaires were returned. Where possible, telephone follow-up was conducted to encourage a response.

These ranged from:
- 5 watt to 875 watt peak photovoltaic arrays.
- as little as $200 to over $14,000 system cost.

The responses were sorted, categorized, and plotted on a map that divided the Province into six regions:

Region	Number of responses
Northeast	4
Northwest	3
Central East (Cariboo)	5
Central West (Chilcotin)	10
Southern Interior	20
Southern Coast & Islands	38

A map of B.C. is included here with points for each of the 80 responses.

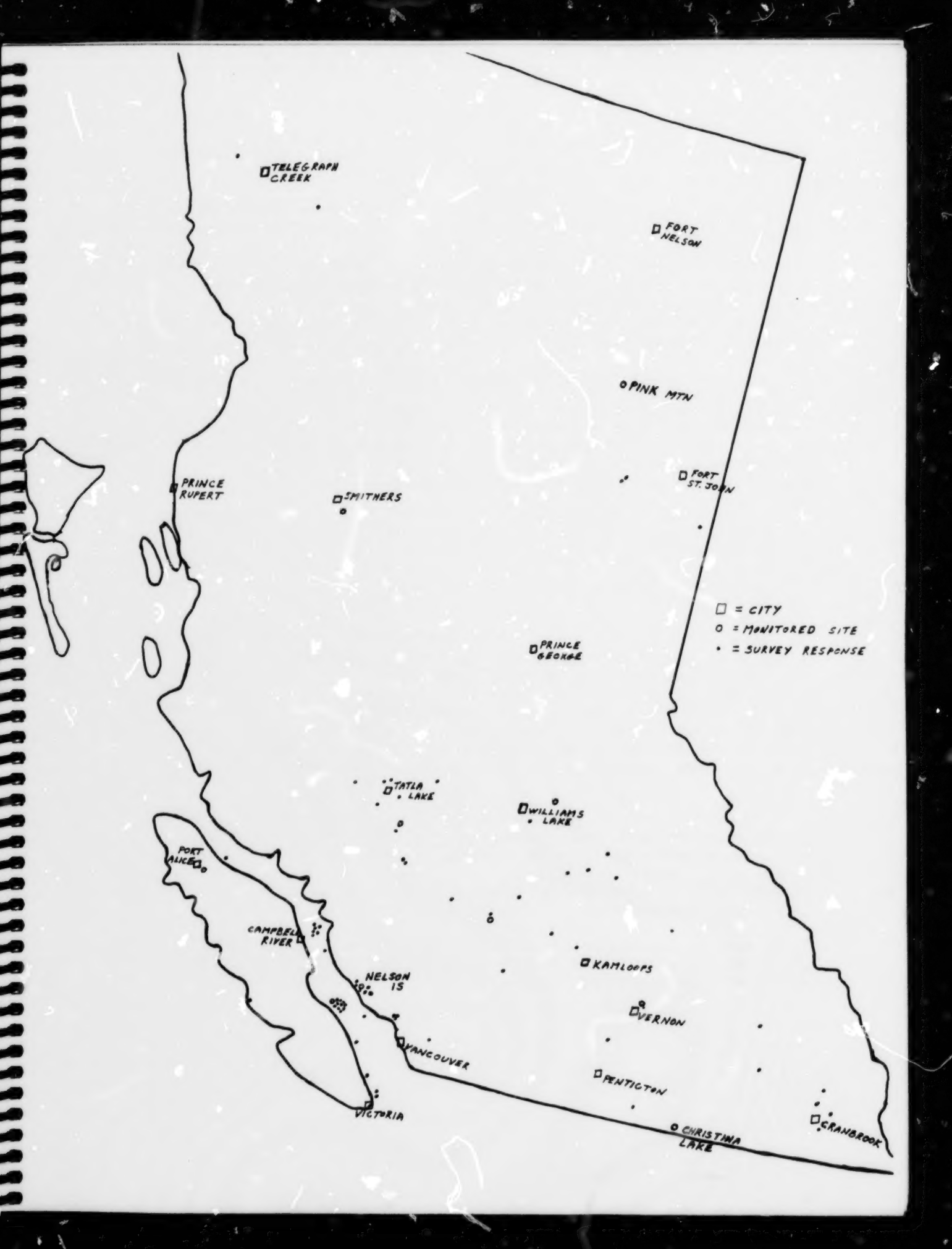
Among the non-responses can be counted 54 reasonably certain identified PV locations , and a further estimated 37 systems. (A significant number refused to cooperate because the survey was "government" sponsored.)

Site Visit & Monitoring:

Of the 80 responses, 49 indicated a willingness to participate in the monitoring program. A further 10 would participate, but low-occupancy (cottages) prevented them meeting the recording requirements.

Ten sites were selected for a detailed system inspection, photographing, monitoring equipment installation, and report.

Selection was based mainly on representative system size and design characteristics, and regional location. Larger systems received some favor because they are considered to be representative of future trends - as module costs drop, and the technology becomes better known. Also, the owner's ability to diligently execute the monitoring program duties was assessed.


TELEGRAPH CREEK
FORT NELSON
PINK MTN
PRINCE RUPERT
SMITHERS
FORT ST. JOHN
□ = CITY
O = MONITORED SITE
• = SURVEY RESPONSE
PRINCE GEORGE
TATLA LAKE
WILLIAMS LAKE
PORT ALICE
CAMPBELL RIVER
NELSON IS
KAMLOOPS
VERNON
VANCOUVER
PENTICTON
VICTORIA
CHRISTINA LAKE
CRANBROOK

MONITORING

Scope:

Within the scope and budget of the project, it was deemed only possible to measure ampere-hour (AH) data. This, as opposed to watt-hour data, is valid and useful in DC electricity because the voltage & current cannot be out of phase, and in battery-based systems voltage variations are not great.

Early-on it was decided that two AH meters, one on the PV input side and one on the load side of the battery, would provide clearer insight to system performance/efficiency, and was affordable. However, battery efficiency cannot be determined as at certain times energy from the "source" bypasses the battery on its way to the loads. Lacking more sophisticated dataloggers, no determination could be made on the effectiveness of any PV regulators. And without pyranometers, maximum potential PV production cannot be assessed.

A six month period, of which at least three months is to be "winter weather", i.e., between October and March, was set-out for the monitoring program

Equipment:

A search turned up only three manufacturers of amp-hour meters, each of which had limited flexibility in certain specifications, besides being relatively expensive.

Then a B.C. manufacturer of electronic controls stated a willingness to design and make a suitable unit at much lower cost (see THES specs in Appendix B). Although an unproven product, the following factors weighed in its favor:

- flexibility in the design - any size DC amp shunt accomodated.
  - operation from 12 to 120 volts DC.
- mechanical counter will not lose reading upon loss of power supply and cannot be reset.
- low power consumption.
- least expensive within similar specification range.
- Canadian product.

There were delays in delivery of the AH meters; and some "bugs" in the initial design required field modification and calibration checks. This set-back, and complicated, the monitoring schedule.

Installation:

Written consent and waiver of liability forms were obtained from each of the ten system owners.

Extra attention was given to selecting an optimally-sized shunt, for accuracy, as there is often a very wide range of DC current flow in a PV system:

- input - if 0 to 15 amps will cover the array output, the rarely-used engine generator (genset) powered back-up battery charger may be rated at 40 to 60 amps or more.

- loads - 0 to 20 amps may cover daily lighting, electronics, and small motor needs; but even brief use of inverter-powered vacuum cleaner, automatic washer, or microwave oven required a much higher rated shunt. For example, the Lasqueti Island site had only 10 amps of 12 volt DC loads, but required a 75 amp shunt to accomodate a 2 KW inverter powering an automatic washer and vacuum.

Special schemes were devised to meet complicated situations. For example, some inverters operate in reverse mode to charge the battery from 120 VAC genset power; this DC charging current would be going backwards through the load AH meter. By having the user reverse the polarity of the shunt sense wires and record the start and finish meter readings, the energy from these charging sessions was accounted for.

Two AH meters were installed in each of the ten systems, often by the users themselves, but subject to wiring verification and calibration check at the site by the Proponent. Users were provided with the meter manufacturers' specifications, project-specific instruction sheets, as well as a verbal education on the purpose and behavior of the meters in their system.

During the course of the monitoring, owners often implemented significant changes to their system. Some of the major ones requiring adaptations in the monitoring equipment are:

- Load side changes, usually inverter additions and/or upgrading, involved supplying a different size DC amp shunt to prevent over-ranging the load AH meter and to maintain an optimum measuring range.

- Three owners gave notice that they would bring another renewable power source on-line. One was a 40 watt small hydro scheme at the Lasqueti Is. site, and two were windgenerators; 200 watts at Port Alice, 50 watts at Horsefly. Since input from these could occur at anytime (as opposed to supervised genset input), it was necessary to install a third AH meter to isolate this energy from PV input.

Data Collection:

Six pairs of monthly recording forms (see Appendix B) were provided per site, one for charging and one for loads; with columns for date, time, AH meter reading, and comments on the weather or load patterns.

Users were instructed to take a minimum of seven daily readings per month as follows:

- 3 during sunny periods
- 3 during cloudy periods
- 1 at month end

Sufficient rows were provided on the forms for additional daily entries and this was encouraged.

Users were requested to always record both meters at the same time, and , if possible, to try to take readings at a similar time each day, preferably after sunset or early the next morning.

Users were asked to mail in completed recording forms monthly for thorough examination. Where problems or discrepancies dictated, follow-up communication took place to remedy these. This process aided in trouble-shooting several major problems within these systems during the monitoring program.

SUMMARIZED DISCUSSION OF SURVEY & SITE VISIT FINDINGS:

Modules:

The vast majority of systems are using single-crystal silicon technology in 30 to 55 watt modules with one manufacturer predominating. Semicrystal, or multicrystal, silicon had about a 5% representation in similar sizes. Amorphous silicon use was only reported in smaller (5 watt) sizes, for battery maintenance, electric fences, or an infrequently-used cottage.

By grouping the systems in descending order of installed peak watts, the Study showed:

Systems	Watts	# of Modules (approx)
one each	875, 516, 432	22, 12, 8
3	400 to 300	8
8	300 to 200	5 or 6
25	200 to 100	3 or 4
19	100 to 50	2
21	less than 50	1

Module manufacturers identified are as follows:

Manufacturer	Systems
ARCO	66
Solarex	4
Tideland Signal	2
Solec	2
Kyocera	1
Photowatt	1
Solavolt	1
Sovonic	1
Solarpac	1
homemade	1
unidentified	5

(some systems use 2 or more brands)

Note in Appendix A (Smithers, Vernon) that modules of greatly varying age, wattage rating, number of cells/module, and brand are used together in one array. This application flexibility, and transcending of technological obsolescence, is seen very positively by users. (In parallel connection there are no restrictions; in series connection, ampere rating should be similar, or full output will not be acheived.)

Systems as old as ten years were surveyed, but only one module problem was reported - a faulty seal. One module had its glass shattered - cause unknown - and replaced with a plastic cover. No other problems were reported in any area; manufacturing, severe weather, vandalism, etc.

"Self-regulating" modules are not commonly understood - it is often thought that a regulator is built-in; in fact, regulation is acheived by a passive relationship between module voltage, battery voltage, and temperature of both.

No significant reports were made of problems in either mounting or wiring the modules.

Installation considerations that were commonly misunderstood or unknown:
- Partial shading (3%) of a module will seriously reduce its output. Any series connected modules will likewise have output reduced.
- Any amount of shading or clouds greatly reduces PV output.
- Orientation of the array should be towards the middle of the site's solar "window", not necessarily due south. This is especially important in B.C.'s mountainous and forested topography. (When considering array orientation, the flatter the slope, the less orientation matters.)

No DC to DC converters for voltage adjustment between array and storage were reported.

For the do-it-yourself PV layperson, it is recommended to shop for modules using ampere output (@ max power) rather than maximum wattage rating. Virtually all modules are designed to charge a 12 volt battery, but due to lack of a standardized industry voltage rating, wattage is sometimes slightly misleading.

Mounting Structures:

The majority of users made a mounting structure themselves using either metal or wood in a wide variety of configurations. In rare instances, modules were simply laid on the roof (Lasqueti Is) or leaned/propped-up against buildings or trees.

Eight respondents are using solar trackers, but only one is a manufactured unit - a passive type. Others were homemade: 5 manually-operated with either zenith or polar axis (see the slides for two innovative designs); and two "active" motor-driven units (notably this latter group was either incomplete, or in need of repair).

To augment power from standard modules, one user reported utilizing flat, anodized aluminum reflectors manufactured for PV use in the United States. In another studied Canadian system, these were found to increase annual output by 25% to 30% with a more even spread around the year than tracking, but require considerable extra space on the mounting structure.
Reflector manufacturers have had difficulty re-tooling for new shapes when module manufacturers periodically alter their frame sizes. After several years, the concept has not "caught-on" with end-users.

Regulators:

Forty-two users reported using no regulator, including 2 of the 3 largest systems. (If the array maximum amperage is less than approx 3% of the battery capacity in amp-hours, and the system is in regular use, PV industry consensus is that a regulator is not needed - see site data for Vernon, Lillooet, Christina L., and Lasqueti Is.)

Manual regulation can be satisfactory because there is often always someone home in a remote residential situation.

Regulator manufacturers were identified as follows:

Manufacturer	Systems	
Specialty Concepts Inc	12	(includes Photron Inc)
SunAmp Systems	4	
ARCO	3	
BOSS	2	
Trace Engineering	2	
Bobier Electronics	1	
locally made	4	(all Lasqueti Is)

Two regulators were reported as failed. One manufacturers' earlier model was specifically mentioned as unacceptable by 2 users. No other opinions or statements were made on regulators.

System Voltage:

A tabulation of reported systems by voltage shows:

2 systems	@	108-112 VDC
1	@	32 VDC
4	@	24 VDC
73	@	12 VDC

(The predominance of 12 volt systems can be largely attributed to the availability of various 12 V components; batteries, lighting, appliances, and tools from the automotive/RV industry.)

Energy Storage:

All respondents are utilizing electrical storage via lead-acid batteries (the only exception was a 30 year old nickel-cadmium bank).

In all instances where storage was purchased new, some type of cycling battery was obtained, not an SLI type (start-light-ignition, = automotive). Mainly, the types supplied were: heavy motive power (forklift), marine deep-cycle, golf cart, recreational vehicle. (In the only exception where SLI batteries were supplied when a cycling type had been requested, replacement was made within a year - see Horsefly site.)

Eleven users obtained used stationary cells of greatly varying age & condition from telephone and power utilities where the application is standby (emergency) communications - for further discussion of this see Problem Areas and the Vernon & Christina L sites.

Six or seven respondents stressed the importance (usually learned the hard way) of good quality, adequate capacity battery storage as the "heart" of the system.

While there were exceptions, typical costs for new lead-acid stoage ranged from $1 to $1.50 per amp-hour at 12 volts.

(See Problem Areas for further battery discussion.)

Inverters:

In 46 of the 80 systems reported, there is no inverter being used.

Twenty-four systems are utilizing solid-state electronic inverters, while 5 have the rotary motor-generator type, plus a few miscellaneous vintage units.

Costs ranged from a maximum of $2450 for a modern, solid-state, 24 volt, 2 KW unit with battery-charging reverse mode option; to $1200 for a 9 year- old 1600 watt rotary; to $15 for a used, vintage, vibrating-reed type; to nil for 2 borrowed units.

(For more on inverters, see Problem Areas.)

Loads:

Loads are grouped and listed here in order, the most frequently reported ones first:

- Lighting. Fluorescent & incandescent (also quartz-halogen) both DC & AC.
- Electronics. Sound system, TV, radio, computer, radiotelephone.
- Pumps. Domestic, garden, and grey water; both DC & AC.
- Washing machines.
- Vacuum cleaners.
- Kitchen appliances. Mostly blenders & mixers, some toasters & microwaves.
- Tools. Saws, drills, soldering irons.
- Fans. Ceiling and table.

(Most conventional refrigeration is too large a load for a practical PV system.)

While not specifically asked:

- 21 users reported that some or all of their lighting is fluorescent.
- several reported electromagnetic interference from DC fluorescent ballasts and solid-state inverters.

Several owners complained of difficulty in sourcing low-voltage DC loads such as lights, appliances, and tools.

Five systems reported food freezers as loads:

- Two owner-developed, super-efficient units of 8 & 9 cu ft. (see Lillooet & Chilko L sites)
- One conventional 5 cu ft box with owner-installed DC motor-compressor. (see Pink Mountain)
- One conventional 21 cu ft. (see Vernon)
- One unknown type (but via the component supplier, is likely to be super-E.)

(For more on refrigeration, see Problem Areas)

Metering & Wiring:

Metering, such as array amps, system voltage, and load amps, was seen in greatly varying sophistication; it is often an after-thought to getting the system running. When eventually added, meters may have too great a range and therefore poor resolution.

Standard 14/2 or 12/2 wiring, as mentioned in the detailed site data here, is certainly adequate for inverted 117 VAC power; and is also often used, and usually suffices well, for 12 or 24 VDC loads, without excessive voltage drop, because of the typically very low power levels used.

Fusing, or circuit-breakers, is crucial for safety of persons and property, but may be neglected in low voltage DC systems. Skin surface electrical resistance in humans is high enough that 12 or 24 volt battery posts can be grabbed with no effect, leading to the belief that these DC voltages are completely harmless. In fact, even the smallest battery capacity in residential use is capable of heating short-circuited conductors, or faulty equipment, to the point of inflaming structures.

Back-up Power:

Twenty-six respondents indicated they are using no back-up power. Most of these had less than 100 watts of PV, therefore indicating very low system load; and many were cottages in part-time use.

Ten systems reported using either windpower (200W to 2000W rated) or waterpower (30W to 1000W output) plants as back-up (one system is using both). Often the seasonal availability of the wind or water resource was good when PV was at its poorest - winter. Seven in this group also make occasional use of a gas or diesel generator.

The remainder use internal-combustion gensets fueled mostly with gasoline, a few with diesel, and fewer with propane, of greatly varying size - 500W to 6.5 KW. Battery charge rates and therefore genset loading also vary greatly.

For specific examples of back-up units, see the detailed site data in Appendix A; the column charts there also show monitored AH from back-up sources.

Performance - owners' comments:

Fifty-seven respondents used one or more of the following words/phrases when asked "From your experience, please comment on the performance & usefulness of PV":

- excellent
- cost-effective
- no maintenance
- quiet
- non-polluting
- wonderful
- trouble-free
- will buy more
- beats operating "noisy, smelly, high-maintenance" gas & diesel gensets.

Fourteen specifically mentioned low winter power as a problem. Only 8 to 10 said the technology is expensive in relation to its output generally.

Three who also use windpower and one who also uses waterpower preferred PV for its low maintenance; two of these mentioned towers as stumbling blocks.

OBSERVATIONS

Load Reduction and Conservation:

As the Introduction states, load reduction and conservation are key elements in enabling small independent power systems to meet minimum cost-performance goals.

The largest electrical loads in a grid-connected household produce heat (domestic water heaters, ranges, clothes dryers). Cost-effective substitutes implemented by PV users are wood fuel, propane & fuel oil, and some solar heat. Real electrical needs are those that cannot be served by other energy sources, e.g., lighting, electronics, motors. While a growing number of loads desired in modern homes are in this latter group, their total consumption is relatively low.

With modern technology, electric energy conservation need not mean using less lighting and appliances, but simply wasting less power:

- Refrigerators and freezers are now available that use only 15% to 20% as much energy as conventional units, and usually operate directly from low voltage DC power.
- Fluorescent lighting is three to five times as efficient as incandescent; fixtures are available for low voltage DC operation, and tubes are now available that produce "warmer", more pleasing light spectrums.
- In virtually all areas of electronics (entertainment, computing, phones, fencers, etc), power requirements have been reduced over the years.
- Permanent-magnet DC motors[1] for pumps, washers, power tools, are 20% to 40% more efficient than AC versions (more so with smaller sizes). Moreover, their use reduces required inverter capacity, eliminates losses that would have been associated with DC to AC conversion, and eliminates single-phase AC motor "starting surge" requirement of the inverter.

The closer a system component is to the end use of the power, the more important its efficiency. Example: an incandescent light, being much less efficient than a fluorescent, uses more current for the same lighting task, therefore requiring not just correspondingly larger array capacity, but also larger: wiring, battery capacity, and control capacity. However, at the generation end of the system, if a particular PV module were to have half the efficiency, and half the cost, of another type, it only means installing twice the area to generate the same power for the same cost - with no further significance to the balance of the system. More generally, losses at any point are reflected back up through the system as larger capacity requirements. So when a significant cost of an electrical system, as for PV systems, is in power controls, storage, and conditioning equipment, attention to efficiency should increase towards the end of the system. The loads therefore become the most important.

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[1] Brush wear in intermittent duty has not proven to be a problem. The refrigerators/ freezers mentioned above are brushless DC.

Too often the cost of a PV system is seen as largely array cost. While these have been high ($15/watt) as little as three years ago, and prices continue to drop, the balance-of-system (BOS)[2] cost must not be overlooked. This cost is, if anything, rising and resulting in a larger percentage of the system cost. Even if modules were supplied at no charge, the power consumption of a typical grid-connected household would entail battery banks, controllers, and inverters so large that few people could afford them.

Load Profile and System Sizing:

Cost-performance decreases when the actual load is different from the design load[3]. Defining the actual load, including times of occurrence, is difficult in the residential applications studied.

The remote lifestyles supported by PV systems are extremely varied. There is no cause and effect relationship based on sophistication (or lack of) of the lifestyle and size of the system. Assumptions about "average monitored" loads or "normal" households for load predictions would yield very poor results. Further, load estimates done by prospective users often are not accurate enough; and often change once the power system is in place.

Two patterns are most typical in setting-up a PV system for the first time:

- The load is adjusted to meet the PV generation that was affordable. Users are quick to grasp that modularity allows them to upgrade the array and increase loads as soon as more funds are available.
- A back-up genset with battery charger is operated as necessary to make-up the difference between PV output and system load.

Control over the owners'/users' behaviour with respect to the power system is nearly non-existent when compared to industrial settings. Due to the small-scale, the low voltage, and almost always do-it-yourself (DIY) installa-tion, these remote residential PV systems are typically in a constant state of flux:

- increasing the size of the array.
- additional loads brought on-line.
- upgrading the size or quality of the DC to AC inverter to meet larger or more sophisticated loads.
- additional power sources (wind, "tiny" hydro) brought on-line creating a hybrid system.
- upgrading of control systems including diversion of excess power.
- replacement and/or upgrading of battery storage.
- troubleshooting and repairs often due to initial DIY installation deficiencies.

These points are meant as an indication to PV designers of the difficulty of defining residential load profiles. (While some are not directly load related, they do affect the system.) See Appendix A, detailed site data, for examples.

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2 Regulator, batteries, meter panel, wiring, inverter, etc.

3 Analogous lessons have been learned in solar hot water installations.

Load Matching:

Since we have little forecasting ability or control over the timing of PV generation, load matching means finding useful purposes for power as close as possible to the time it is generated. Especially at Canadian latitudes, we need to usefully load the system in harmony with the wide seasonal range of our solar resource. (For contrast, consider a PV system designed for the Canadian latitude and climate with only domestic lighting as a load - long summer days of PV production would have little or no load during the short nights; whilst overcast, short winter days of low PV output would not meet lighting loads during the long winter nights.) While the charts in Appendix A give an indication of the seasonal insolation variations, keep in mind when studying the columns that the effect of regulation, automatic or manual, is to restrict PV output to 10% or 20% above load (ideally).

Power generated when there is no immediate load (battery is fully charged) is wasted. Load matching efforts should be made at both the design phase and during system operation[4]. Two possible energy management solutions are discussed (storage management is shown to be costly and/or inefficient, while load management requires some operational input by the user):

1/ Storage management:

Seasonal: It is not cost-effective in residential systems to store electrical energy via batteries from one season to another - 2 to 4 weeks is approximately the limit. The cost of the required capacity, and losses by internal self-discharge, render this impractical.

Weekly and/or daily: The storage component could be designed to be nearly always at some partial state of charge, so as to be able to accept input anytime, but this would greatly sacrifice lead-acid battery longe-vity via sulphation. Further, power run into and, later, out of the battery, has both an energy conversion loss (approximately 20%) and shortens battery life by additional charge/discharge cycling.
This approach should be rejected.

2/ Load management:

Seasonal: Users should be encouraged to incorporate into their systems loads which use more power in summer than in winter so as to match the available seasonal energy flux. The best examples are:
- irrigation pumping during the growing season.
- refrigeration - best when the cabinet is outside.
- air conditioning - only the evaporative-type would be practical.

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[4] Confer with Soltek's findings in "Development of a Solar Power Supply for Remote Aquaculture Operations" - prepared for EMR's Renewable Energy Branch, August 1987.

Daily (three categories):

A/ Some loads are deferable to sunny periods if users can make themselves available at that time:
- clothes washing
- vacuum cleaning
- sewing, computer
- use of shop or construction power tools
- electric chainsaw, electric lawnmower, "weedwacker", etc.

B/ Other loads are not only deferable (to greater and lesser degrees) but can be automated (or manual) to occur when sunny, or at least during daylight:
- food freezers and refrigerators controlled by timers.
- if a pump is used, energy is more efficiently stored via water in a reservoir (domestic or irrigation) than chemical conversion in batteries.

C/ Certain less useful, non-critical, loads can also be automated to occur as a lowest priority via inexpensive "surplus power diversion" circuitry when the battery is fully charged:
- ventilation - living space, greenhouse, etc.
- electric resistance water heating (a solar domestic hot water heater would also be recommended).
- a second battery bank for reserve (often this is whole or part of a previously retired set).

All load management categories have the same purpose: attempting to make the useful load profile match the generation, thereby keeping the array "working" with a higher duty cycle and/or more efficiently (than battery charging), to improve cost-performance. But it must also be recognized by both designers and users, that there will be trade-offs between the maximum utilization of the randomly available PV power, user convenience, and system wear & tear.

Referring to "Load Management, Seasonal" above, were a load or a combination of loads to require extraordinary summer season power, a solar "flat-plate" tracker may be employed. At Canadian latitudes, a tracker which maintains proper orientation (+- 15 degrees) can increase array output by at least 50% on sunny days from approximately March to September, but the winter season advantage may be only 5%. A factory-made, passive-type tracker may be cost-effective given:

- it is carrying at least 4 full-size modules (200 watts). For smaller arrays, purchasing additional modules is more cost-effective.
- a useful summer season load is present to utilize the extra output.

A manually-operated tracker, where the structure is fabricated locally and the user is available for adjustment 2 to 3 times a day, is very cost-effective.

Problem Areas:

Storage:

Lead-acid is the only storage battery technology which is presently cost-effective in residential applications (even in industrial applications it predominates). Unfortunately, it is not only woefully misunderstood, but much mythology[5] exists which is difficult to counter. Some examples are:

- "Industrial, clear-case, 2 volt stationary cells are the best for home power storage". Since these are too expensive new, used cells from telephone and power utility companies are invariably sought-out; age and condition vary greatly and the purchaser is at risk. The reputed long-life of these cells is due mainly to the "float" standby application, with possibly as few as 10 to 20 deep cycles in a 20 to 25 year life.
- "If the case is large, the battery must be heavy-duty and will serve well". Thin plates for engine-starting (SLI) purposes or thick plates for deep cycle use may be installed in identical cases.
- "Batteries not in use for extended periods will be OK without maintenance". Normal internal losses (self-discharge), which vary with battery type, are not understood.

Four further points which are not "myths", but are not understood:

- Any amount of time a lead-acid battery is in a discharged state, even partially, it is wearing-out (sulphating). Some users unknowingly cycle the battery in a low state-of-charge range; the same cycling in an upper state-of-charge range would greatly increase battery life.
- Lead-acid batteries do not require, nor benefit from, any "exercise".
- Paralleling of batteries to obtain the necessary capacity invites problems (usually towards end of life) of one failed unit becoming a load (discharge path) for the remaining good ones. It is wiser (but initially more expensive) to install cells (batteries) in series only, each of which has the required capacity.
- Lead-acid batteries should be topped-up with distilled water.

Since considerable energy can "disappear" within battery storage, it is deserving of improvement through better understanding. Even though battery sales for home power systems do not represent a significant market portion, most suppliers are knowledgeable of cycling applications and, if asked, will usually deliver a suitable product.

Ventilation:

The lead-acid battery loses capacity at temperatures lower than 25^{0} C, due mainly to increased electrolyte viscosity. Further, freeze damage is possible in colder climates if kept outside in winter (depending on the day-to-day specific gravity). While an underground housing and/or insulated boxes are possible, these will still be cool, and will likely reduce the attention and maintenance that batteries receive.

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[5] "Mythology" is not used idly here, but refers to widespread, nearly unanimous, beliefs unfounded in fact.

So, while not their personal preference, most owners realize the battery storage will serve better and longer if inside the heated home. Their reluctance to do so is centered around the production of explosive gases.
Due to a lack of good guidelines, a sane approach, and simple effective designs, the subject of battery ventilation has created much confusion and paranoia. Information from industry is hard to find, and may not be relevant. Providing good ventilation while maintaining rated temperatures can be costly in terms of space heat energy. A recent magazine article described a closed system of small vinyl tubes from each cell vent cap manifolded to a larger rigid plastic pipe and vented outside[6] .

Battery state-of-charge (BSOC) assessment:

Devices for BSOC measurement (a "fuel" guage) are often requested by home power system owners.

Even with good quality hydrometers, it is difficult to obtain an accurate reading due to bubbles sticking to the float, float friction, or electrolyte surface tension. With frequent use, only extreme care can prevent acid spillage or contamination of the cell, besides being time consuming. Amp-hour integrators are far too expensive at the present time for the residential market.

Presently, a battery voltage meter (preferably digital) along with users' experience/judgement, is universally relied upon for assessment of BSOC. (Neither has the electric vehicle industry yet solved this problem at a reasonable cost.)

When studying the graphed results of monitoring in Appendix A, look for the input (all sources) to exceed the load by at least 10% to allow for the AH efficiency of lead-acid batteries (as an ideal situation reference).

Inverters:

As little as 4 to 5 years ago, inverters were a major problem for remote residential dwellers with DC energy storage amidst an AC society.

Rotary motor-generator units had been available for many years, were robust enough, and had clean waveforms; but lacked high efficiency, particularly at low load, and had moving parts requiring maintenance. Solid-state units at that time had better low load efficiency and no moving parts, but were either expensive and/or notoriously unreliable; or were too easily overloaded, and lacked surge capacity for induction motor starting; and all consumed too much power when idling. This difficult era is now over.

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[6] See "Venting Lead-acid Cells", Home Power Magazine, issue #6, Hornbrook, CA.

Several manufacturers now have field-proven track records with reasonably priced solid-state power inverters embodying these essential features for remote residential AC power:

- High efficiency throughout the power range.
- Very low idle current. Inverters can now be left on continuously without an energy penalty.
- High surge capacity for starting induction motors.
- Protective circuitry for shut-down before failure occurs.
- Adequate voltage and waveform regulation to prevent damage to loads from improper voltage and/or distortion; for tolerance of loads with poor power factor.
- As an option, some units can reverse the mode to charge the low voltage DC battery from a source of 120 VAC, 60 Hz (genset); and automatically transfer current AC loads.
- One manufacturer has introduced modularity, or "stacking", to inverters.

Refrigeration:

Refrigeration was once (1983) refered to as the "Achilles heel" of photovoltaics. In a conventional home, food refrigeration/freezing is often the largest electrical load after the heating loads of domestic water, cooking, and clothes drying. The largest load in the largest system studied here is a conventional 21 cu ft freezer.

As mentioned above in Conservation, super-efficient units are now available, and with DC motors. Even with very high initial purchase price, these are cost-effective in the long term. More importantly, neither the materials nor the processes used in the manufacture are inherently expensive, so as production quantities increase, costs should drop significantly.

Brief mention is deserved of 3 owner-developed energy-efficient solutions at sites studied here:

- at Pink Mountain, a conventional 5 cu ft cabinet received a 12 VDC motor-compressor and operates in a cool location.
- at Lillooet, an 8 cu ft commercial ice-cream freezer was super-insulated with urethane foam, and received a water-cooled condenser and a 110 VDC permanent-magnet motor.
- at Chilko Lake, a new, super-insulated, 9 cu ft cabinet was constructed and cooled with a 12 VDC condensing unit similar to the one at Pink M; it is located on the north side of the house.

(See slides and slide text - Appendix C - for more on these units.)

Modern gas refrigeration (propane) is an option for PV users. The technology is now greatly improved in efficiency from previous decades-old designs, but units are considerably more expensive than conventional vapour-compression, and there are fuel & fuel handling costs.

Some Comparisons of Remote Residential Power Technologies:

General comments relating to remote site power development:

Exceedingly few remote dwellers can afford to bring professional expertise and/or installation contractors out to their site. Were this not the case, virtually every aspect of these systems would be changed, including cost-performance and payback. Whether or not such services would be cost-effective is highly site/technology specific and is not the topic here. The point is that the tasks of resource assessment, system design, and installation vary greatly in difficulty between the candidate technologies, placing the more difficult ones at a disadvantage for success in the DIY environment.

Common to all these technologies (except gensets) is the requirement for electrical energy storage. It serves two purposes:

- to store energy for use at times when none is being generated.
- to store energy to meet peak loads above the normal generated levels. (A side benefit is the battery's ability to stabilize energy flows by accepting and discharging large amounts of power within a narrrow voltage range.)

An important categorization of these technologies by prospective users will be between those converting "free" energy (renewables), but with high up-front capital costs; and those with low to medium initial capital costs, but requiring continual fuel, operation, & maintenance costs. (Remote lifestyles are not conducive to obtaining loans.) Noise and pollution are also important factors.

Users should be cautioned when considering any technology not in common use at this scale (<100 KWH/mon):

- it will be difficult to get information and other's experiences.
- equipment, not to mention parts & service, may be hard to get.

No technology can be successful and widespread without an educational and commercial infrastructure.

Photovoltaic systems:

PV systems have possibly, or potentially, the highest cost/KWH; however, they are on the rise in use and popularity. Eighty-five percent of respond-ents to this survey expressed "complete satisfaction", raved about the "near-zero maintenance", and "excellent performance" (with winter season exceptions). Many are, or plan to, upgrade their system.

Throughout B.C., the survey found small, grass-roots style, PV sales businesses springing-up by individuals who were particularly impressed and successful with the technology for themselves. This is not occurring for small, battery-charging, hydroelectric technology; while a similar phenomenon did occur in windpower in the late '70's and early '80's (partially spurred by US Federal tax credits), it collapsed just after mid-decade. It is here suggested that PV will carry-on as the technology most suitable for the remote DIY population.

Reasons for this expectation are:

1/ UNIVERSAL APPLICABILITY - All locations receive solar energy to greater and lesser degrees.
2/ SIMPLICITY - No special skills required for these 5 tasks:
> Site assessment - Bright sunshine hour data (10 to 30 year averages by month) is available for 51 locations in B.C. and is reasonably valid on a regional basis. In a worst case scenario, the annual total bright hours range is 2.3 to1 within B.C.
> Equipment sizing - Modular nature of the array reduces the need for accurate initial system sizing (this will change slowly as BOS, less modular, becomes larger percentage of system cost).
> Siting - sunny versus shady locations are easily distinguished.
> Installation - Rarely is any significant transmission distance necessary. Nor easements, Crown land permits, or resource "rights".
> Maintenance - The solid-state technology has a proven and well-accepted near maintenance-free operation.
3/ RELIABILITY - Long module warranties (10 years), and even longer field-proven performance track record.
4/ No obsolescence - new photoelectric materials, processes, modules, etc, will be compatible with existing or vintage technologies.
5/ Decreasing costs for modules - costs for other technologies are, if anything, rising.

Small hydroelectric battery-charging systems[7]:

Hydropower at this scale has taken a beating socially and media-wise due partially to the charisma of windpower and photovoltaic's "high-tech" profile. In a comparison, one popular magazine article said "experts agree" that a hydro site capable of less than 500 watts continous output is not worth bothering with. It is safe to say that a wind or PV system with a similar energy output would require at least a five figure investment. Half a kilo-watt "sounds" small, while a comparable 3 KW to 4 KW PV or wind generator "sounds" larger.

What is often overlooked in these comparisons is capacity factor - hydro is 24 hrs/day - and the effect of the storage component. The Lasqueti Island hybrid system amp-hour data in Appendix A shows these effects well. Where suitable streams are present, battery-charging hydro systems can "out cost-perform" other technologies by one, sometimes two, orders of magnitude.

In addition to this main criteria of $/KWH, hydro's continous generation is a "benefactor" to the lead-acid battery:

- less capacity is required because there are no periods of autonomy.
- power output is always present to help drive loads, thereby reducing the number and depth of discharge-charge cycles.
- re-charging will be quicker following periods of heavy loading, in most instances.

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[7] For an introduction, see "Very Small Systems Under 2 KW" by R. Mathews - "Small Hydro Canada 87" (EMR) conference proceedings.

Yet battery-charging small hydro continues to be overlooked or under-estimated. The following reasons are given as potentially responsible for this state-of-consciousness in the market:

- It is not commonly known that, for hydropower this small, a "penstock" may not be required. An existing domestic pipeline often suffices, greatly reducing both capital and labour costs of the power system.
- Unless the stream is close by, or can be easily piped there, potential users are suspect of DC transmission losses. A rural "mythology" exists about this. The fact is that higher AC voltages can be generated & transmitted, then stepped-down and rectified into the battery, without significant cost increase.
- Sunlight is the same everywhere, but gravity-flow water sources have many different head & flow combinations which cannot be accomodated efficiently by one standardized unit of energy conversion equipment. So the technology is not only not modular, but requires several shapes & sizes of turbines. Moreover, the interrelated hydraulic, mechanical, and electrical characteristics (head, jet velocity, RPM, output, efficiency, generator voltage curves, etc) are far from commonly understood, so that most sites require applications assistance from designers.
- Some potential users are concerned about their rights to the water resource over the long-term, and are often mis-informed by local hearsay on this legal aspect.

In any final analysis, there are only a fixed number of usable streams.

Small Wind Energy Conversion Systems:

SWECS (of 3 KW or less for comparison purposes) are the most difficult of residential alternative technologies to implement. But the romantic aspects of "windmills" and their residual popularity from past decades when PV was non-existent or too expensive (and at sites where waterpower was not an option) keep them popping-up as candidates for remote power generation.

Assessment of the wind resource is difficult and extremely site specific in mountainous areas such as B.C. Experience has shown that private individuals are, at best, reluctant and, typically, refuse to budget either time or funds for wind monitoring equipment. Some difficulties they face are:

- Wind (air) cannot be seen for visual estimation as can sunlight or water.
- Fluctuations in windspeed are rapid, by minutes & hours; by contrast streams vary monthly & seasonally.
- Because output of the windgenerator will vary as the cube of the wind-speed, small errors in speed measurement become large errors in power predictions.
- In mountainous areas, available wind data (airports) may be invalid one kilometer away; by contrast, solar radiation data is valid on a regional basis.

Installation of windgenerators and their towers is difficult and dangerous; they are neither modular nor portable.

Several experienced consultants/installers had this advice for successful residential windpower systems:

- Wind-deformed vegetation or trees should be in evidence.
- Most prospective users tend to overestimate potential wind generation; they are not aware that windspeeds under 13 kmh are not worth counting
- The windgenerator must be mounted on a tower at least 6 meters above all obstacles for a 150 meter radius.
- Prospective users should be mechanically-inclined and willing to climb the tower routinely (or use a tilting-type tower); they will not likely be able to afford a serviceperson for maintenance or repairs.

More positively, a well-sited SWECS in a good wind regime can provide a satisfactory $/KWH return for the investment.

Thermal electric generators:

Solid-state thermoelectric generators, while similar to PV in direct energy conversion and no moving parts, are so inefficient (2% to 3%) and expensive ($15 to $20/watt) that the heat source needs to be virtually cost free for residential use. This technology's application to woodstoves, the nearly universal remote site heating appliance in B.C., is experimental at this time. Some recent production runs have had poor output and many failures, the latter due to excessive thermal cycling and/or excessively high temperatures (the typically manual regulation of temperature is not satisfactory).

Steam engines or turbines, in spite of their long successful history, have not found a market niche in small-scale residential applications. Suspected reasons for this are low efficiency (especially homemade), danger of pressurized boilers, and B.C. law which requires licensed operator above 1/4 horsepower.

CONCLUSIONS:

Residential PV systems are as varied in size and sophistication as their owner's:

- budget.
- needs.
- knowledge of the technology.

These survey results show an overwhelming majority of present users expressing overall satisfaction with the technology's contribution to their lifestyle, in a market-driven economy. This is a crucial test, regardless of cost/KWH considerations.

Survey responses indicated no major problems in setting-up and operating a PV system by do-it-yourselfers. (One exception is the storage component, but even here the technology is adequate; the remedy lies in a better understanding by users.)

Moreover, it is the technology's simplicity, reliability, and universal applicability that is the key to its success. PV modules are certainly the most user friendly independent electricity source; unaffected (in low voltage configurations) by either open or short-circuit in bright sun.

Much opportunity still remains for cost-performance optimization, mainly due to large seasonal variations in Canadian insolation. Some techniques are relatively easily implemented, but others will depend on users' knowledge of energy flows, electricity, storage battery behaviour, and willingness to accept some lifestyle adaptations.

Remote residential photovoltaic systems should continue to gain acceptance and more widespread use, especially as module costs drop and more efficient loads (appliances) become practical. Food refrigeration/freezing play an important role in the perceived usefulness of a remote power system; while super-efficient units are now expensive, good reasons are given for future cost reductions.

RECOMMENDATIONS

To its present extent in British Columbia, and in a market-driven environment, residential photovoltaic technology is successfully serving the needs of remote dwellers.

To further this extent, regional short courses & workshops should be given to spread this information, and provide a proper introduction to the technology. The design phase concepts of electrical conservation (efficiency) and load reduction, without depriving the lifestyle, and the operational concepts of load matching should receive emphasis.

In particular, educational information on the technical aspects, selection, use, ventilation, and care of lead-acid storage batteries for PV systems must be written in a concise and readable format for the layperson. Overcurrent protection (fusing) could be included with this in a pamphlet and disseminated via PV and battery suppliers.

Residential PV case studies and comparisons to both other alternative energy options and conventional gensets (and grid power) should be included. Participants attention should be brought to the excellent potential of even the smallest of hydropower sites; and for those considering windpower, the necessity of measurement and study of the wind regime must be driven home.

Brief mention should be made of the current state of development of technologies which, although not mature, may have captured the imagination of potential users via the mass-media or word-of-mouth, with unrealistic performance claims. Remote lifestyles have great difficulty obtaining up-to-date and accurate information on prototype or demonstration-stage equipment, and waste time & effort trying to following these up.

For the forseeable future, residential PV systems will need custom design. Recommended is an interview/educational approach between the prospective user and the designer, utilizing examples of typical systems and the cost/benefit effect of adding, changing, or removing certain components or loads; within the characteristics of the particular site.

For the do-it-yourself PV layperson, it is recommended to shop for modules using ampere output (@ max power) rather than maximum wattage rating. Virtually all modules are designed to charge a 12 volt battery, but due to lack of a standardized industry voltage rating, wattage is sometimes slightly misleading.

APPENDIX A

Names and locations of the ten monitored sites:
(in order by installed peak watts - largest first)

Name	Latitude	Longitude
Vernon	50° 20'	119° 10'
Chilko Lake	51° 40'	124° 15'
Lillooet	50° 50'	122° 10'
Pink Mountain	57° 05'	123° 00'
Smithers	54° 40'	127° 05'
Horsefly	52° 20'	121° 30'
Christina Lake	49° 05'	118° 10'
Lasqueti Island	49° 30'	124° 20'
Port Alice	50° 25'	127° 20'
Nelson Island	49° 45'	124° 10'

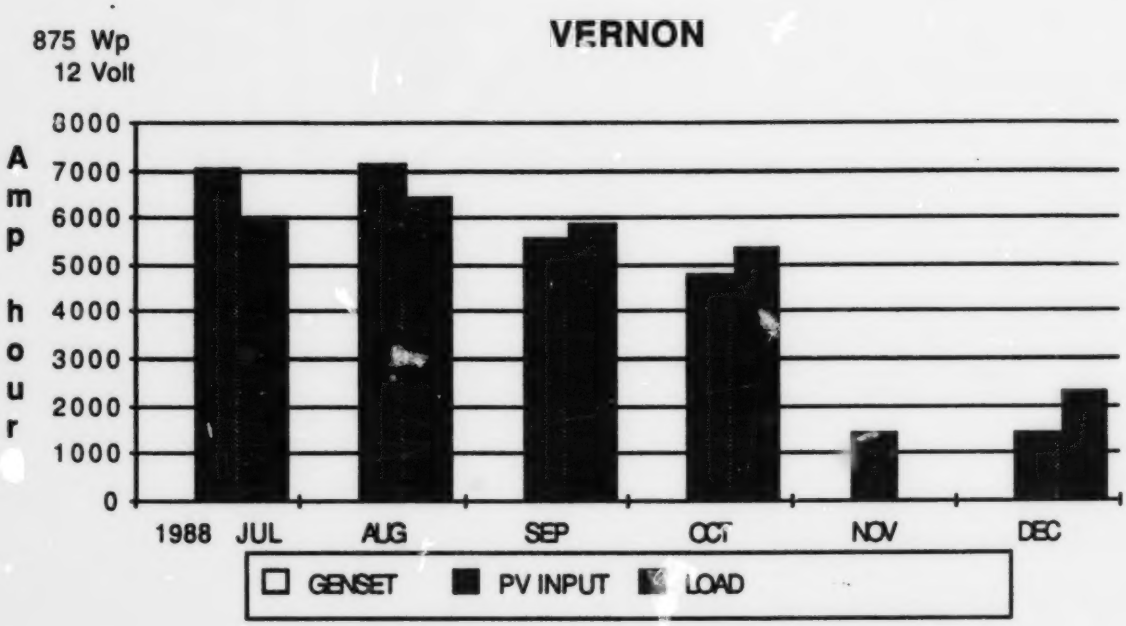
All sites were inspected between May 15 and Aug 1, 1988.

ABBREVIATIONS REFERENCE:

Wp	= watts peak
AWG	= American Wire Guage
H	= horizontal
AH	= amphours
QH	= quartz-halogen
fluor	= fluorescent
incand	= incandescent
auto	= automatic

Parentheses following each module description, states the number of silicon solar cells per module.

Parentheses following battery description or genset price, states whether new or used when purchased.



- The genset was not used until Oct 16 when the failing battery bank was replaced. So much genset power was needed that the owner felt it would be misrepresentative of normal operation, and so did not monitor the energy.

- It is possible on these charts for the load to exceed all inputs in a given month as the battery will have supplied the difference.

SITE: VERNON, Nominal system voltage: 12

All modules are ARCO.

ARRAY: 875 Wp one 37W 16-2300, six 35W 16-2000, eleven 40W M-73, four 47W M-75

AGE/(cells): 5 yr (35) 5 yr (33) 3 yr (33) 3 yr (33)

COST: $12,000. total

LEAD-IN WIRE: 15m of #6 copper NOV 88: added three 35W 16-2000.

MOUNT: Steel frame on roof of house, owner-made.

ORIENTATION: 36° SW (fixed) SLOPE: 60° from H

SHADING: Minor tree shading, east & west only; open to south.

REGULATOR: none. Manual disconnect if overchg. No diode; photocell controlled relay

STORAGE: 1440 AH twelve (2 x 6) 2V GOULD FTA 13 (720 AH ea)

TYPE: stationary AGE: 15 yr

LOCATION: semi-heated basement COST: $60. (ex-telephone co)

MAINT. water once every year PROBLEMS: voltage too low

WIRING: Fused DC circuits. Conventional circuit-breaker panel & 14/2 for AC.

DC LOADS: 9 lites (3-9W & 1-20W fluor, 1-15W QH, 4-25W incand); bathroom fan; TV, VCR; radio, cassette player; electric piano.

INVERTER: VANNER 20-2200W ($1800); first unit exch. for "demand start" feature.

AC LOADS: 21 cu ft conventional freezer; sm auto washer; water pump; microwave oven; juicer; clothes iron; power tools.

LOAD MATCHING: Seasonally - exc. Freezer is the main load.

Daily - fair. Some effort is made to use loads in daytime.

BACK-UP POWER: DC Genset,100amp HONDA/CHRYSLER (homemade), gas, new, $500.

CHARGER: none. Direct DC to battery. Rheostat control on alternator field.

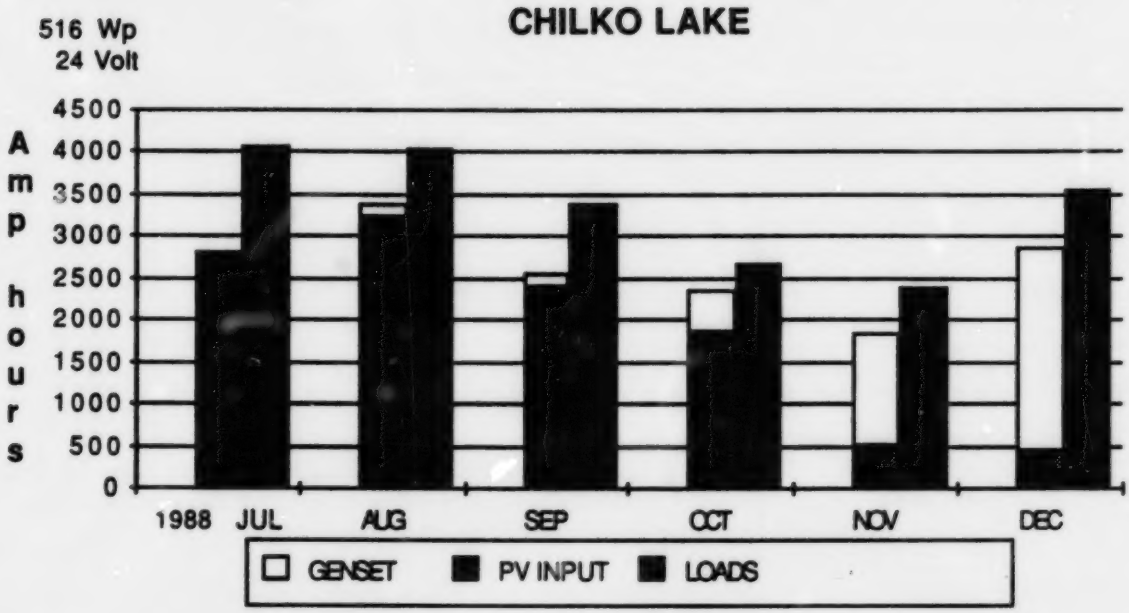
USE: winter only - typically 18 hr/mon.

PROBLEMS: In early 80's, lack of information on PV systems, wiring in particular. Low voltage DC appliances more expensive. PV modules too expensive. System needs caretaking for holidays as freezer cannot be turned-off.

COMMENTS: This is the largest system identified by this survey. The owner feels that because of extraordinarily cloudy weather this fall (88) and very poor battery condition, that the monitoring was not representative of typical system operation. The batteries were replaced on Oct 16 with a similar set of used telephone com-pany cells which were unfortunately little better.

Alternatives: In 1982, grid power was 2.5 KM away ($18,000); by 1988, extensions to neighbors reduced this to 1.2 KM. There is no small hydro potential.

Windpower was not pursued because significant wind velocities appeared to be of short duration only. Solid-state thermoelectric devices designed for wood stove operation were purchased, but had low output and failed within 1 to 2 years.



- The load side of this system is complicated by an electronic comtroller for operating 12V loads (freezer, radiophone, some lighting) from a center-tapped 24V battery by switching the 12V loads from one side to the other. As wired for monitoring, only half the unit's AH's at 12V should have been counted towards load for analysis & charting at 24V. It is suspected that this did not work correctly, and that all the AH's at 12V were integrated, explaining the consistent load over input shown. Because much of the load goes out through the inverter at 24V and the proportion cannot be determined, no compensation or adjustment is possible here.
- Input data for this system is still worth presenting; both for the quantity of genset power required seasonally; and for the total input power when compared to the Vernon system as both are heavily loaded, and in a dry climate, but Chilko L., with only 60% of the peak wattage, has a tracker.

SITE: CHILKO LAKE. Nominal system voltage: 24

ARRAY: 516 Wp twelve 43W ARCO M-53 (36)
AGE: 1.5 yr
COST: $6000.
LEAD-IN WIRE: 25m of doubled #2 alum

MOUNT: Steel frame, manual drive tracker; axis adjusts for slope chg, owner made
ORIENTATION: 8° SW axis,140° track. SLOPE: 28° from H (seasonal adj)
SHADING: Some deciduous trees & hills in winter only.

REGULATOR: PHOTRON BVR-24-30; batt temp comp; no diode-has relay(.02V drp @3a)

STORAGE: 690 AH six (2 x 3) 12V CBC SS-8D (230 AH ea)
TYPE: deep cycle AGE: 5 yr
LOCATION: buried insulated box COST: $1000.
MAINT: clean & water every 6 mon, equalize every mon. PROBLEMS: none

WIRING: An electronic VANNER VOLTMASTER supplies 12V loads from 24 V batt.

DC LOADS: 12V loads: super-eff 9 cu ft freezer; lites, 4-20W QH & compact fluor; piston pump (house); radiophone; 24V centrifugal pump (garden).

INVERTER: TRACE 2024, 2KW, 24V, with battery charging mode option($2450). Smaller HEART INTERFACE 300W used for better eff on TV & fish tank.

AC LOADS: Washing mach; kitchen appl; pwr tools; TV & VCR; fishtank lite & pump

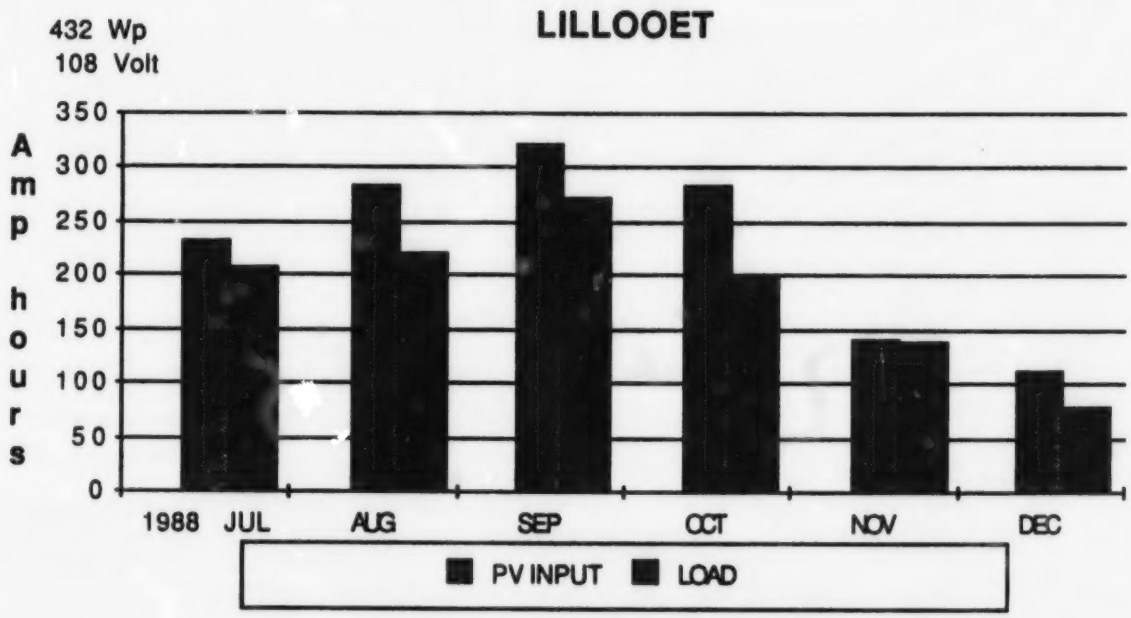
LOAD MATCHING: Seasonally - exc. Freezer & garden pump use summer power.
Daily - good. Freezer only on in daytime; laundry then also.

BACK-UP POWER: DC Genset, 80 amp owner-made, diesel & 24V truck alternator.
CHARGER: none. Direct DC to batt. TRACE chg mode (40A) is not high enough.
USE: see accompanying charted data.

PROBLEMS: Previous 33 cell modules had insufficient voltage to: make-up for lead-in wire losses; equalize the batteries at their maximum voltage.

COMMENTS: Monitoring of this system consistently showed the load AH exceeding input AH. Meter calibration and site wiring schemes were checked. It is suspected that the Vanner Voltmaster 24V to 12V controller is responsible, but this could not be verified.

Alternatives: Grid power is 60 KM away. A nearby stream freezes-up in winter and was perceived as having too low a head. Windpower is considered to have good potential and installation of a unit is now planned. The Chilko River is 30m away and may have sufficient velocities for a current turbine. Solid-state thermo-electric developments are being followed in search of cost-effective devices.



- Note how the freezer, which is the main load, causes good load matching to the seasonally available energy. The freezer was taken off-line on Nov 24 for several months.

SITE: LILLOOET . Nominal system voltage: 108

ARRAY: 432 Wp four 55W PHOTOWATT 7010(36), four 53W ARCO M-55(36)

AGE:	6 yr		2 yr
COST:	$2700.	+	$2400. = $5100.

LEAD-IN WIRE: 12m of #8 AWG copper

MOUNT: Steel (angle iron) frame on shop roof, ownermade.
ORIENTATION: 5° SE (fixed) SLOPE: 73° from H (adjustable)
SHADING: none nearby. 2 hr of winter sun lost to mountains (west).

REGULATOR: none. Manual disconnect if overcharging. Blocking diode(.8Vdrop @3A)

STORAGE: 180 AH 18 (2 x 9) 90 AH 12V VARTA RV24

TYPE:	RV (rec vehicle)	AGE:	6 yr (now dying)
LOCATION:	heated shop	COST:	$1050.
MAINT:	clean & water every 6 mon	PROBLEMS:	none

WIRING: Conventional 2 circuit fuse panel and 12/2 shop & house wiring.
Transmission to house is 75m of #8 AWG copper.

DC LOADS: Super-eff 8 cu ft freezer, 2-20W & 2-40W fluorescent, misc incand, auto washer, vacuum cleaner, sewing mach, elec chair saw, shop tools.

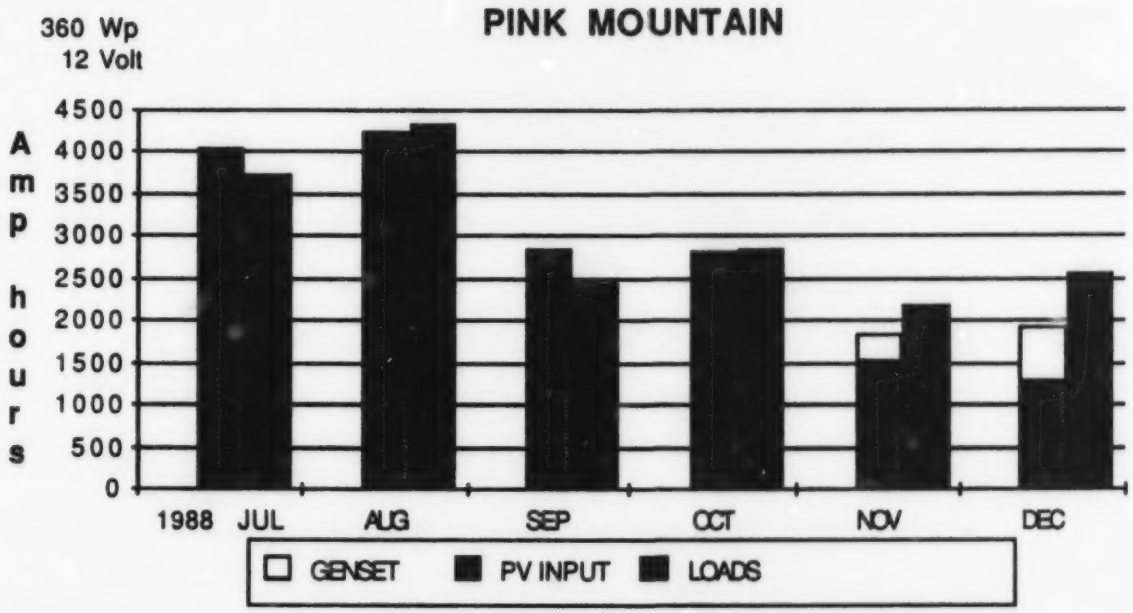
INVERTER: none. AC LOADS: n a

LOAD MATCHING: Seasonally - exc. Freezer, outside, is the main load.
Chainsaw used in spring w/excess pwr.
Daily - good. 2nd line of loads above used when sunny

BACK-UP POWER: AC Genset, 4KVA ONAN, gas, ? yr old, poor cond, $850 (used).
CHARGER: Variable transformer to rectifier (DIY) to batt, manual control.
USE: In the past, averages only two 8 KWH charges per winter.

PROBLEMS: Early-on, charging 108V with 4 modules required an internally-tapped center battery (54V,1 side/day); it corroded every 3 mon; now 8 panels

COMMENTS: This system was designed in the early 80's when inverters were unreliable, less efficient, and expensive. It was noted that many conventional AC loads (incand lights; universal motors in vacuum, sewing mach, blender, and hand-held tools) operate well on 108 VDC with only occasional switch problems. AC induction motors (washer, freezer, large tools) were replaced with DC motors. Even with the array left at 73° slope all year, excess spring & summer power is still available. Eight 36 cell modules charging nine 12V batteries performs well in winter due to temp coeff; power falls off 1/3 in hot weather, but is usually excess then anyway. Alternatives: Grid power is 10 KM away. An excellent stream is 2 KM away but transmission line easement problems prevented development. A 1 KW windgenerator was operated in 1984, only to discover that no wind is available in winter, the only time PV power is insufficient. Wind other times was turbulent. Unit was sold.



- The freezer was taken off-line on Aug 30.

- During the monitoring, the owner estimated the potential AH available from the array after the regulator stopped the charge; this totalled 2187 AH for Jul to Nov, mostly, of course, in the summer.

SITE: PINK MOUNTAIN. Nominal system voltage: 12

ARRAY: 360 Wp eight 45W KYOCERA LA36LT45 (36)
AGE: 3 yr DEC 21/88:
COST: $3800. (farm) -added 4 identical modules
LEAD-IN WIRE: 13m of #10 AWG copper. (non-tracking)

MOUNT: Steel frame, vertical axis (turntable), manually driven tracker in yard.
ORIENTATION: rotatable SLOPE: adjusted 4 times/yr to solar normal.
SHADING: Deciduous trees (virtually insignificant) in winter only.

REGULATOR: B.O.S.S. MC8010-12-30 (30amp) incl Schottky diode (.31V drop @15A)

STORAGE: 636 AH three 4V MAGNACHARGE DTL-25 (new)
TYPE: marine deep cycle AGE: 1.5 yr
LOCATION: heated indoor closet COST: $1130.
MAINT: clean & water every 6 mon; equalize once/mon w/genset PROBLEMS: none

WIRING: House originally (1982) wired for DC power with #8 copper. Fuse panel.

DC LOADS: 34 lites mostly fluorescent, 5 cu ft freezer, water pump, radiophone.

INVERTER: Two TRACE;1512 Turbo (2KW) & 612 (600W); $1700 both, wholesale.

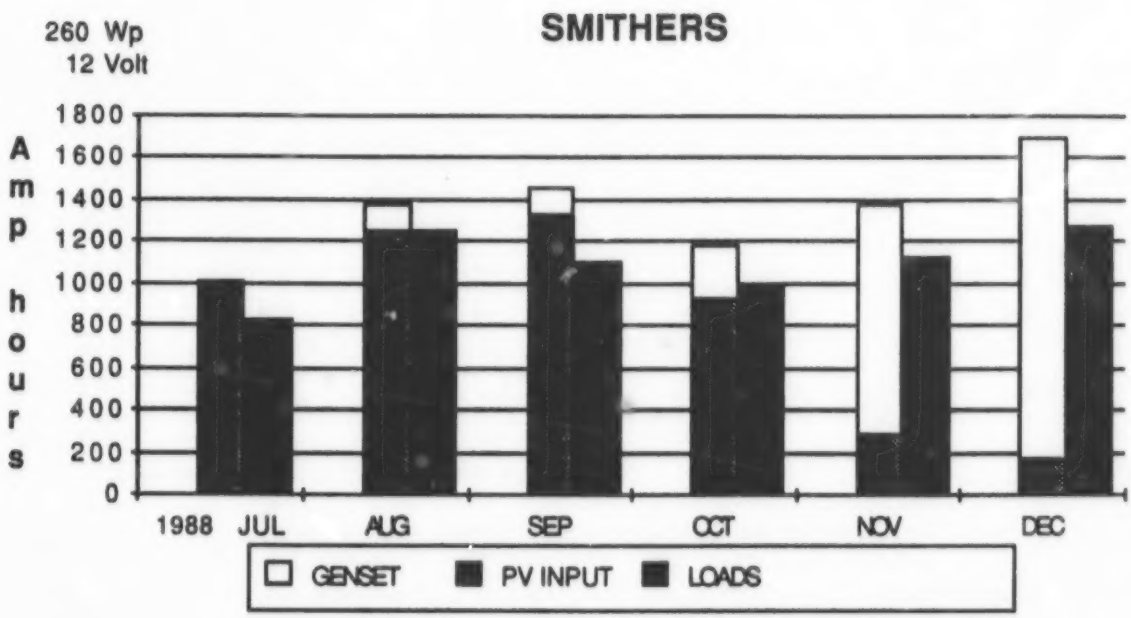
AC LOADS: Wringer washer, gas dryer, vacuum, photocopier, hair dryer, food mixer toaster, clothes iron, rug shampooer, TV & Sat dish, pump, power tools.

LOAD MATCHING: Seasonally - fair. Freezer is good, but small, & located in cool room, not outside; and the lighting load is large.
Daily - good. Many loads can be & are used in sun or daytime.

BACK-UP POWER: AC Genset, 5KW homemade, propane, 7 yr old, good cond, $1200.
CHARGER: 30 amp SONIC auto.
USE: none in '87; Nov & Dec '88 - approx 20 hr/mon .

PROBLEMS: none.

COMMENTS: By substituting propane energy for water heating, cooking, and refrigerator requirements it can meet well, and by good management of efficient loads, this PV system supports a lifestyle similar to conventional grid-connected homes. Winter months' bright sunshine hours are the highest in B.C. at this northern, dry (east of the Rockies) location, greatly reducing back-up power requirements. An excellent battery ventilation system was made of small plastic tubes manifolded to a larger pipe and vented outside.
Alternatives: Grid power is 75 KM away. The only stream is very small, has little head, and freezes totally for much of the winter. Wind was visually assessed as swirling & intermittent; and too costly. Thermal electric (woodstove) was investigated and deemed to be too costly.



- Load increase in Aug is due to the addition of the 2 KW inverter (with reverse-mode charging option) and AC loads.

- This is a good example of typical PV system operation.

SITE: SMITHERS. Nominal system voltage: 12

ARRAY: 260 Wp one ARCO M61, two ARCO 16-2000, two ARCO M53, two SOLAREX HE-60G

AGE:	7 yr	7 yr	1.5 yr	4 yr
WATTS/(cells):	30 (30)	35 (33)	43 (36)	37(36)
COST:		$3250. total		

LEAD-IN WIRE: 43m of #6 copper (before Aug was Alum - see PROBLEMS here)

MOUNT: PHOTRON adjustable (slope) mount, on 1m hi wood platform 30m fr house
ORIENTATION: due south (fixed) SLOPE: 3 settings; 35°, 55°, 75° from H
SHADING: a few deciduous trees in winter only.

REGULATOR: PHOTRON BVR-12-30, 30 amp, no diode - uses relay.

STORAGE: 430 AH 4 (2 x 2) 6V MAGNACHARGE 2XH215(new)
TYPE: golf cart AGE: 1.5 yr
LOCATION: semi-heated pantry COST: $500.
MAINT: clean & water every 3 mon PROBLEMS: none

WIRING: Owner installed fuses, then to conventional distrib panel & 14/2 wiring.

DC LOADS: color TV, 7-15 watt incandescent, 1-30 watt & 3-20 watt fluorescent, 40 watt CD stereo system, ceiling fan.

INVERTER: TRACE 2012, 2 kW; added Aug 10. Has reverse mode charging capability

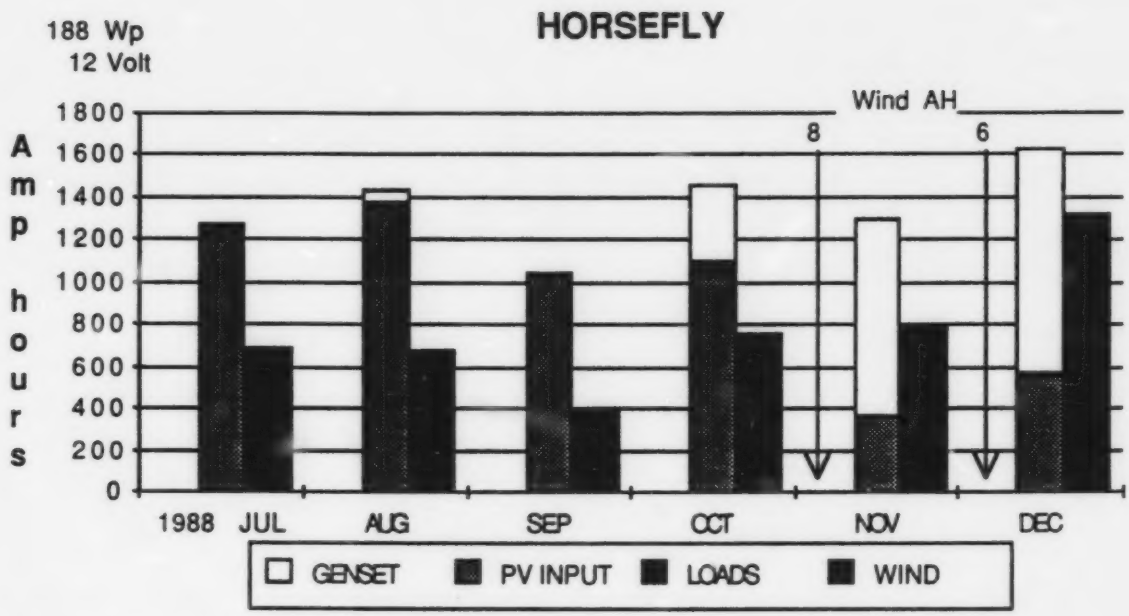
AC LOADS: VCR, microwave oven, vacuum cleaner; added Aug 10.

LOAD MATCHING: Seasonally - poor. Lighting is the main load. (AC loads will help)
Daily - poor. Most power is used at night.

BACK-UP POWER: AC Genset, 1.4KVA HONDA, gas, 4 yr old, good cond, $900. (used)
CHARGER: 10 amp SILVER BEAUTY auto; 110 amp inverter (programmable).
USE: Spr & sum - 2 hr/mon; fall - 16 hr/mon; winter - 60 hr/mon.

PROBLEMS: Thick hoar frost on modules requires applying methyl hydrate to thaw.
A previous regulator (ARCO BP 12-20) stopped PV charge at 13.5V, which is too low, and sulphated the previous batteries (RV type).
One 14/2 circuit (for TV) required upgrading to #8 due to voltage drop.
Buried #6 Alum w/nicked insulation corroded, was replaced w/#6 Cu.

COMMENTS: This family of 4 is very enthusiatic about their independent PV sys-tem and pleased with its performance. To improve load matching, it was recom-mended that garden irrigation water be pumped with excess spring & summer PV power where a gasoline powered unit is now used.
Alternatives: Grid power is .7 KM away and without extraordinary difficulty. There is no possibility for small hydro. Wind may be possible, but no instrument monitoring was done; a tower was erected, but when a mail-ordered 450 watt wind-generator turned out to be a rip-off, the technology was dropped.



- See comments on corresponding detailed data page.
- The 50W wind-generator was brought on-line on Nov 19. It is level with the roof peak; the owner realizes it should be higher and may raise it.
- Three 48W modules were added Dec 5 with better (due south) orientation.
- The high load in Dec was partly due to non-conserving visitors.

SITE: HORSEFLY. Nominal system voltage: 12

ARRAY: 188 Wp four 47W ARCO M-75(33)
AGE: 1 yr DEC 5/88:
COST: $1600. -added 3 KYOCERA 48W modules
LEAD-IN WIRE: 5m of #10 AWG copper

MOUNT: Steel frame hangs from sheltering eave and wall of house, owner-made.
ORIENTATION: 44° SW (fixed) SLOPE: 64° from H
SHADING: Some deciduous trees, due south only.

REGULATOR: SCI-2, 30 amp, batt temp comp; no diode, uses relay (.05V drop @9A)

STORAGE: 900 AH (est) ten (2 x 5) 6V DELCO 717A (new)
TYPE: truck & tractor AGE: 1 yr
LOCATION: heated indoor batt room COST: $750.
MAINT: clean & water once every 6 mon PROBLEMS: see below

WIRING: #10 AWG copper throughout; circuits are fused.

DC LOADS: 12 lites(4-30W fluor,2-60W incand, &misc); pump; sm solidstate cooler

INVERTER: HEART HF1200U($1700); Oct 88 upgraded to TRACE 2012 w/charger opt

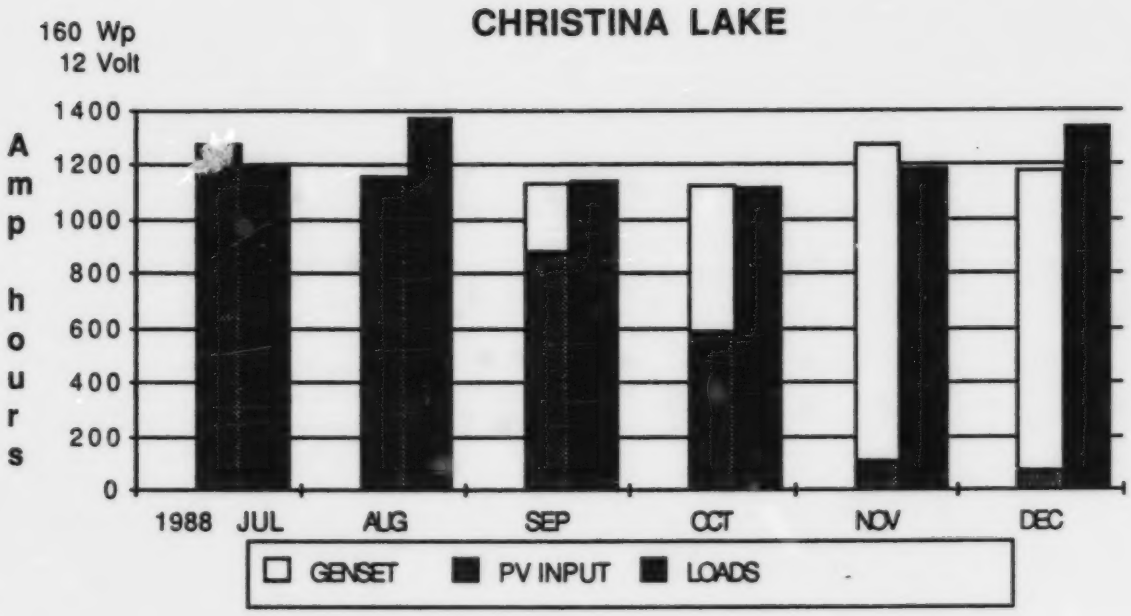
AC LOADS: washing machine; computer, printer, & fax; stereo tape deck;
sm vacuum cleaner; sm clothes iron; circular saw & drill; block heater

LOAD MATCHING: Seasonally - fair. Water pump irrigates summer garden.
Small cooler uses more power in summer.
Daily - fair. Many loads can be used when sunny/daytime.

BACK-UP POWER: AC Genset, 2KVA HONDA, gas, new, exc cond, $1200.
CHARGER: TRACE inverter (Oct 88) has 110 amp programmable charge mode.
USE: This first year was not normal due to battery problems.
- RUTLAND 50W wind-gen; pole-mounted at roof level (too low).

PROBLEMS: Many birds roost on the array which then requires frequent cleaning.

COMMENTS: Despite the AH meters showing input energy markedly exceeding the loads, battery voltage never rose to a corresponding level (that all loads were through the AH meter was triple checked; and the voltmeter was calibrated). An inverter with powerful charging-mode capabilities was installed in Oct for back-up. But with even lower voltages, often below 12, the many parallelled non-deep cycle batteries became suspect and were replaced in Nov with 660 AH of a golf-cart type.
Alternatives: Grid power is 2 KM away ($20,000). A very small waterfall 225m away might be developed for 1 to 2 amps, but was rejected in favor of retaining the aesthetic value of the falls. A 50W RUTLAND wind-generator was installed on Nov 19/88, and separately monitored (see chart for output AH).



- Genset data was estimated as amps times hours by the owner.

- The AH data accumulated by this Project greatly helped the owner to understand the condition of the battery, i e, not receiving enough charge.

SITE: CHRISTINA LAKE . Nominal system voltage: 12

ARRAY: 160 Wp four SOLAREX SX-100 (40)
AGE: 7 yr (2 yr here)
COST: $1200 total (used)
LEAD-IN WIRE: 2.5m of #14 AWG to fuse, 1.5m doubled #14 to batt (both Cu)

MOUNT: Steel brackets supporting panels on flat roof, owner-made.
ORIENTATION: true south (fixed) SLOPE: 50° from H
SHADING: south horizon is treetops - only 2 hrs direct sun Dec 21.
- insignificant in summer.

REGULATOR: none. Blocking diode on purchased meter/fuse panel (.7 V drop @ 1 A)

STORAGE: 216 AH three 4 V EXIDE TPPC
TYPE: stationary AGE: unknown
LOCATION: outside porch COST: $100 total (used)
MAINT: water once every 6 mon PROBLEMS: none (see comments below)

WIRING: Main battery fuse. Meter/control panel provides fused load circuits.

DC LOADS: TV(4A), stereo(1A), 24 & 36 watt lights(1ea), blender, drill, soldering iron, nicad battery charger.

INVERTER: 180 watts (unknown brand) used only to rotate antenna.

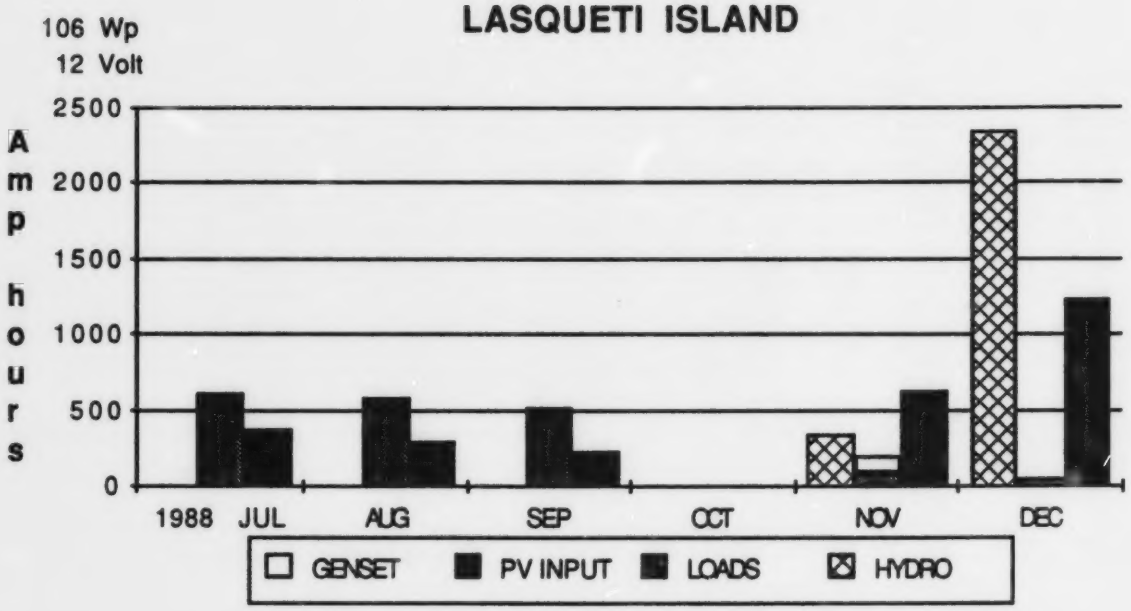
AC LOADS: antenna rotator (44W)

LOAD MATCHING: Seasonally - poor. Lighting is the main load.
Daily - poor. Most power is used at night.

BACK-UP POWER: AC Genset, 3.8KVA HONDA, gas, 6 yr old, good cond, $2000.(used)
CHARGER: 60 amp CENTURY automatic.
USE: Nov to Mar - about 9 hrs/mon typical.

PROBLEMS: Insufficient PV power in winter - purchased 60 amp charger.

COMMENTS: Two months into the monitoring program, it was pointed out to the owner that energy production was barely keeping up with consumption (see AH charts), and that neither internal battery losses nor overcharge requirements were being met. A recently obtained meter also showed battery voltage falling. Due to poor knowledge of the behaviour of lead-acid batteries, genset charging sessions were stopped when battery voltage reached 12.8 - at least 14.5V should have been acheived. The battery continued to deteriorate, requiring large quantities of genset power (see the AH charts) in order to maintain adequate system voltage.
Alternatives: Grid power is 1.6 KM away (about $20,000). A nearby small stream dries-up in summer, and freezes totally in winter. Wind velocities were considered to be either insufficient or too far away. Rotating 12V batteries between vehicles (charged when driving) and house was possible, but labor-intensive and unpleasant.



- The 40W hydro-generator was brought on-line on Nov 23 with a capacity factor very close to 100%. (The stream dries-up in summer.)

- At the same time, a 2 KW inverter and more loads were added to utilize the extra power.

- Both AH meters were inadvertently damaged in Oct, and most of the month passed while replacements were obtained & installed.

SITE: LASQUETI ISLAND. Nominal system voltage: 12

ARRAY: 106 Wp two 53W ARCO M-55 (36)
AGE: 2 yr
COST: $1000.
LEAD-IN WIRE: 9m of #12 AWG copper

MOUNT: none. Modules are laying in vee of roof.
ORIENTATION: 22° SW SLOPE: 12° from H
SHADING: Trees - winter, fulltime; east & west in spr, sum, fall.

REGULATOR: none. Car alternator diode to prevent backfeed (.85V drop @ 4 amp)

STORAGE: 220 AH one 12V CBC SS-8D (Oct 88 added 2 similar batteries)
TYPE: deep cycle AGE: 2 yr
LOCATION: outside under eave COST: $200 ea (new)
MAINT: water every 6 mon PROBLEMS: none

WIRING: Conventional #12/2 and fuse panel.

DC LOADS: misc incandescent, one 13 watt PL fluorescent, portable stereo/radio.

INVERTER: TRACE 2012, 2 KW; added Nov 23, '88.

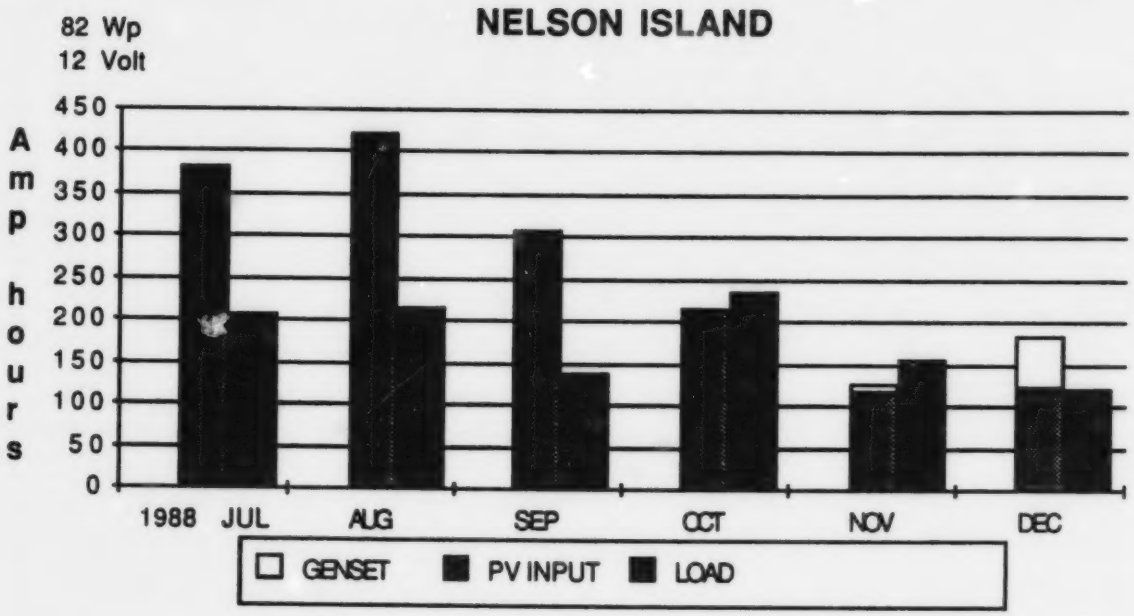
AC LOADS: automatic washer, vacuum cleaner, blender - a/o Nov 23, '88.

LOAD MATCHING: Seasonally - poor. Lighting is the main load.
Daily - poor. Most power is used at night.

BACK-UP POWER: AC Genset, 1.5KVA HONDA, gas, 8 yr old, fair cond, $400 (used).
CHARGER: 60 amp SUN auto supplies 50% spr & fall, 90% winter (estimates)
USE: winter-20 hrs/mon; spring & fall-16 hrs/mon; summer - none.
- Small hydro (Nov 23), 3 amp-24 hr/d, homemade (motorbike gen)

PROBLEMS: none

COMMENTS: A typical ultra-simple use of PV technology on a very small scale. However, this system is evolving; on Nov 23, a 2KW inverter was added, along with increased storage capacity, to drive large AC loads. At the same time, a small hydro unit (see above) was brought on-line which eliminated any need for genset charging of the battery. A third AH meter was supplied to quantify this energy and interesting comparisons of the results can be seen on the chart. Sufficient water is only available from November to March, but this is an excel-lent match to the PV's good summer performance.
Alternatives: There is no grid power on the island. Windpower was considered viable (neighbors use wind), but installation & maintenance skills required would be too great for a single woman. Tidal energy 50m away appeared feasible, but little knowledge of this technology was available and implementation looked difficult.



- Although it does appear the PV regulator is set too high and overcharging the battery, the 5 amp peak array is unlikely to damage the 460 AH battery.

SITE: NELSON ISLAND Nominal system voltage: 12

ARRAY: 82 Wp one 35W ARCO 16-2000(33), one 47W ARCO M-75(33)

AGE:	5 yr		2 yr
COST:	$525.	+	$675. = $1200.

LEAD-IN WIRE: 8m of #16 AWG copper

MOUNT: Steel frame on side of house, owner made.
ORIENTATION: 35° SW (fixed) SLOPE: 30° from H (seasonally adjusted)
SHADING: forested to the southwest.

REGULATOR: SUNAMP PBR 12-8-LC, 8 amp, incl Schottky diode (.33V drop @1.2A).

STORAGE: 460 AH two 6V VARTA P-125 (new), two 6V VARTA GC 3000(new)

TYPE: golf cart	AGE:	3.5 yr		2 yr
LOCATION: outdoor porch closet	COST:	$150.	+	$220. = $370.
MAINT: clean & water once every 6 mon	PROBLEMS: none			

WIRING: Conventional #14/2 and fuse panel, but no fuse from batt to this panel.

DC LOADS: 5 x 15 watt incandescent, cassette tape player, AM-FM radio, B&W TV, radiophone, nicad battery charger.

INVERTER: none

AC LOADS: na

LOAD MATCHING: Seasonally - poor. Lighting is the main load.
Daily - poor. Most power is used at night.

BACK-UP POWER: AC Genset, 3KW ACKLAND'S, gas, 6 yr old, good cond, $1000.
USE: 16 hrs/mon all year; mostly other uses - water pump, pwr tools.
CHARGER: 10 amp ALLANSON auto; only Oct to Mar, supplies approx 25%.

PROBLEMS: When regulating, the SUNAMP unit seems to cause radio interference - cured by turning on a lite to pull voltage down a bit, regulator goes off.
Cells low on electrolyte, learned to add water, & distilled, more often.

COMMENTS: This is a classic "cottage" PV system. The owner lives there 8 to 9 months per year, but this is just one adult. The genset is used to pump both domestic and grey water, for power tools, and misc; the charger to the PV battery is only turned-on if necessary.
Alternatives: There is no grid power on the island. A potential stream for small hydro is too far away. Windpower was considered, but the winds seemed "erratic" and the owner was concerned about maintenance of moving parts.

SITE: PORT ALICE. Nominal system voltage: 12

ARRAY: 84 Wp two 42W ARCO M-65 (30)
AGE: 2.5 yr
COST: $1400.
LEAD-IN WIRE: 10m of #6 copper

MOUNT: Wooden frame tilts modules to east on SW facing 45° roof slope.
ORIENTATION: south (fixed) SLOPE: 50° from H (fixed)
SHADING: none.

REGULATOR: none.

STORAGE: 240 AH six 2V HART HFS 17 (used)
TYPE: stationary AGE: 20+ yr
LOCATION: outside under house COST: $120.
MAINT: clean & water every 6 mon. PROBLEMS: excessive voltage drop on 20A load in cold weather.

WIRING: Conventional fuse and distribution panel.

DC LOADS: Lights-10 to 60 watt incand & fluor; stereo record & tape player; radio; nicad charger; percolator; toaster; absorption fridge(excess power only)

INVERTER: ATR Model RSD, 100 watt, vibrating-reed type (vintage unit was a gift)

AC LOADS: Ceiling fan.

LOAD MATCHING: Seasonally - fair. Lighting is main load. Fridge used as dump load
Daily - fair. Most pwr used at night. Fridge used as dump load.

BACK-UP POWER: AC Genset, 3KW HONDA, gas, 10 yr old, fair cond, $1200. (new)
CHARGER: 50 amp vintage unit.
USE: nearly eliminated by output of wind-generator (installed Dec 87)
- 200W WINCHARGER, 8m tower, open exposure on lakeshore bench

PROBLEMS: Adjusting energy use patterns to fit variable energy input-being solved by increasing the variety of input sources and larger battery storage.

COMMENTS: Initial problems with wiring the AH meters remote from the shunts caused delays in monitoring. On Nov 20/88, while the owner was away, a bear attacked the house short-circuiting and completely discharging the battery, and causing some anomalies in the monitoring data. A third AH meter was supplied to isolate wind output, but except for 2 short tests the generator of the windplant was not repaired in time (before Jan) for its output to be included in the monitoring results.

Alternatives: Grid power is 20 KM away. A suitable stream (now piped for domestic water) was not developed for battery-charging hydroelectric due to lack of knowledge of the technology - plans for this are now underway.

EXISTING PV INSTALLATION SURVEY (BRITISH COLUMBIA)

GENERAL:

System owner: _____ Telephone: _____

Mailing address: _____

Nearest contact by phone: _____ Nearest community: _____

Geographical location of the PV system: _____

_____

Circle the category which best describes the use of the power:

(ranching) (farming) (aquaculture) (homestead/residential) (other_____)

SYSTEM DESCRIPTION:

How many panels & what type (make & model): _____

System voltage: ____ Batteries(make,model,size): _____AmpHr

Is a charge regulator used? _____ type or manufacturer: _____

Approximate cost of: panels $_____batteries $_____

inverter (if any) $_____whole system $_____

Age of: panels _____ yrs batteries _____ yrs inverter (if any) _____yrs

In your opinion, does your system have any unique or innovative aspects?

_____

LOADS:

List the lights, appliances, pumps, tools, etc., that are powered by this system: _____

_____

BACK-UP POWER:

What other energy source provides power to this system (batteries) when needed? _____How much compared to PV power? _____

PERFORMANCE:

What problems have occurred and how were they resolved? _____

_____

_____

_____

From your experience, please comment on the performance & usefulness of PV:

_____

_____

_____

MONITORING:

Are you willing to have electric meters (amp hour) installed and be responsible for noting the readings at least 7 times per month for a 6 month period? _____

Is any monitoring information already available? _____

PLEASE RETURN TO:

T.H.E.S. AMPHOUR ACCUMULATOR FOR D.C. SYSTEMS

Revision 1.0 - February 1989 - Printed in Canada

FUNCTION

The T.H.E.S. amphour accumulator is designed to totalize the output of D.C. current power sources. The current shunt of the desired amperage is supplied with the accumulator as specified by the customer. Current shunts of any ampacity may be used. The unit is powered by power taken from the current being measured under normal conditions, but may be powered by a separate power source if this is desirable. Under any hook-up, the minus power supply must be commoned with the CS+ sensing input.

READING

The elasped amphours between two readings of the accumulator are calculated by the following formula. "K" is the amp rating of the 50 millivolt shunt being used. Note that the right-hand two digits on a 6 digit accumulator are t· the right of the decimal point (e.g. 0345.34).

amphours elasped = (final reading - initial reading) X (K)

for example: 3321 amphours = (345.34 - 278.92) X (50 amp shunt)

ADJUSTMENTS

There is only one adjustment. A gain (or span) adjustment is available under the lid by means of a small screwdriver inserted into the hole in the circuit block. Clockwise will increase the gain (i.e. make the count faster). Adjust by applying a 50 mV signal across the current shunt terminals; applying power between the power supply + terminal and current shunt +; then adjusting for one count every 36 seconds. Continuous internal auto-zeroing is used to eliminate the need for a zero adjustment.

CONNECTIONS

The positive connection should be made to the +12V up to +60V source. Power supplies up to 160 Volts D.C. may be accomodated as an option by means of the special 120 V connection.

+120V - Connect to a 120 V D.C. source if this option is ordered.
+12-48V - Connect to a 12 to 60 V D.C. source if this is the voltage.
-CS - Connect to the current shunt end connected to the minus of the current source to be measured.
+CS - Connect to the current shunt end connected to the minus of the load connection. This also must be common with the minus power supply terminal.
(-) PWR - Minus power supply input. This terminal must be commoned with the +CS terminal. The units are shipped with a jumper in place.

The standard accumulator design assumes for simplicity that the shunt is placed either on, or immediately adjacent to the accumulator, and that the same wire can be used to connect from the shunt to both the +CS and (-)PWR terminals. If the shunt is mounted remotely, the accumulator power consumption current (about 15-20 milliamps) that is drawn from the same wire can create an error in the reading, noticable as a drift in the zero calibration. To keep this as small as possible, mount the shunt near the accumulator, and use a good sized wire (up to AWG #14) for the CS+ connection to the shunt. (up to 1 foot of AWG #14 can be used, as an example). If longer runs must be used between the monitor and the current shunt, then remove the jumper on the terminal strip between +CS and (-)PWR and instead run two separate wires to the same shunt terminal.

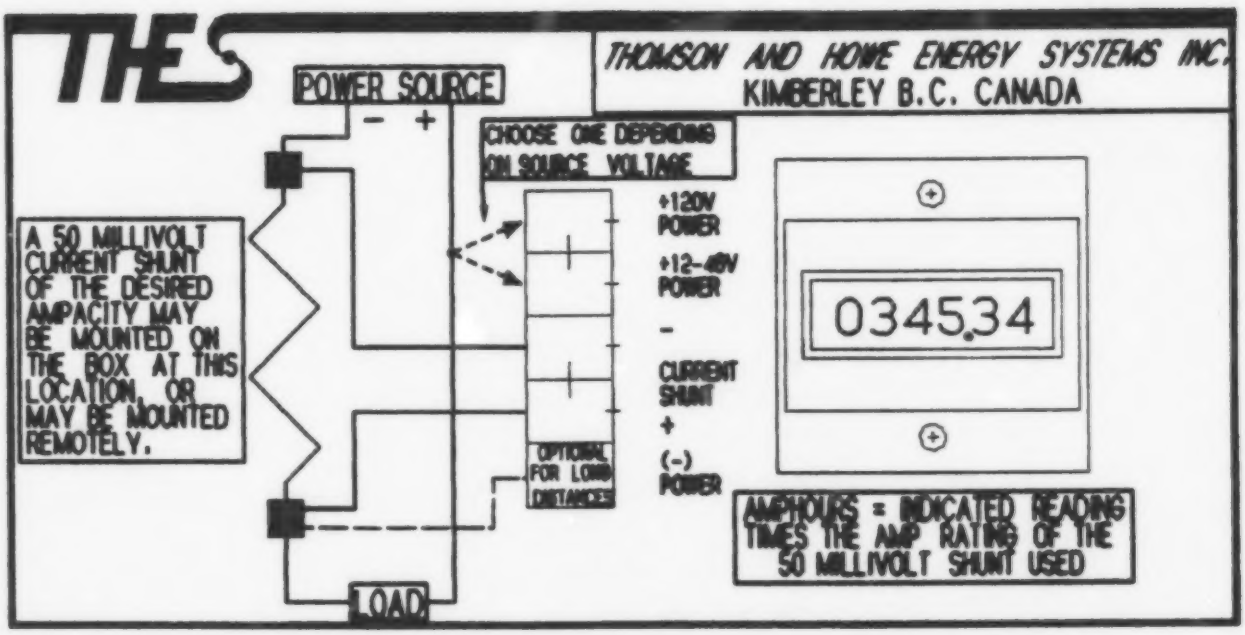
SPECIFICATIONS

Full scale accuracy	<1% (adjustable) *
Adjustable Span range	25% of range
Zero offset voltage	<50 microvolts
Nonlinearity	<0.1% of full scale
Input impedance	10 K ohms
Maximum count before overflow	416 days @ continuous full load
Overload capability without error	100% (100 millivolt)
Reverse current subtraction	minimum 1 count equivalent before loss of totalization. **
Power supply current	15 - 20 milliamps
Power supply voltage	Minimum 10.8 volts (12-48V terminal) Maximum 80 volts (12-48V terminal)
Optional supply voltage	Minimum 80 volts (120 volt terminal) Maximum 160 volts (120V terminal)

* For those who are interested, the potential actual error, expressed as a percentage of the measured current, can be determined by the following formula:

ERROR (as a percentage of reading) = 1% + (0.1% X shunt rating / measured amps) + Shunt error

** Note that the mechanical accumulator only increments and does not decrement. The reverse current subtraction rating is the minimum amount of current flowing in the reverse direction which will be remembered internally and subtracted from subsequent normal current flow, delaying the next increment. If more than one or two count's worth of reverse current is encountered, then reverse current in excess of the circuit's memory capacity will not be accounted for in the accumulation.


THES
THOMSON AND HOWE ENERGY SYSTEMS INC.
KIMBERLEY B.C. CANADA
POWER SOURCE
- +
CHOOSE ONE DEPENDING ON SOURCE VOLTAGE
A 50 MILLIVOLT CURRENT SHUNT OF THE DESIRED AMPACITY MAY BE MOUNTED ON THE BOX AT THIS LOCATION, OR MAY BE MOUNTED REMOTELY.
+120V POWER
+12-48V POWER
-
CURRENT SHUNT
+
(-) POWER
OPTIONAL FOR LONG DISTANCES
034534
AMP/HOURS = INDICATED READING TIMES THE AMP RATING OF THE 50 MILLIVOLT SHUNT USED
LOAD

SCALE: FULL SIZE

MONITORED DATA FROM CHARGING - _____

Meter # _____ Shunt _____ System Voltage _____ Month _____ 19 __

Date	Time	Weather Conditions	Voltage if Sunny or Charging	Meter Reading	Optional	
					AH	Cumulative

MONITORED DATA FROM LOADS - _____

Meter # _____ Shunt _____ System Voltage _____ Month _____ 19 __

				Optional	
Date	Time	Extraordinary Usage	Meter Reading	AH	Cumulative

APPENDIX C - SLIDE TEXT

VERNON:

1. General view of the site with 875 Wp array on roof.
2. Array showing 4 different modules (all in parallel) with lead-in wire.
3. Basement battery storage (1440 AH @12V) showing AH meters, and 2.2KW inverter secured to joists.
4. Different view of same location; shows relay for night-time disconnect and wiring.

CHILKO LAKE:

5. General view of the site showing 516 Wp array on tracker about noon.
6. Same view on same day at sunset. Tracker is manual drive.
7. Array support and tracker frame (painted green) with "outboard boat-type" control wheel & ropes.
8. More details of the tracker support frame.
9. Battery storage (690 AH @ 24V) is outside below grade, cover removed.
10. Top to bottom: charge regulator, AH meters, 2KW inverter; upper left is 24V to 12V power conditioner.
11. Owner-made 9 cu ft super-insulated freezer on north side of house.
12. 12V DC motor-compressor for the freezer showing fan-forced, air-cooled condenser.

LILLOOET:

13. General view of the site showing the 432 Wp array on shop roof.
14. Older & newer modules of the same power all in series. At certain seasonal sun angles, the galvanized roof reflection gives a 20% power boost.
15. Strut length can be seasonally adjusted, but hasn't been for several years.
16. Battery storage (180 AH @ 108V nominal), AH meters, other metering, and wiring in the shop.
17. Owner-modified 8 cu ft super-insulated freezer, outside on south-facing porch of house.
18. 110V permanent-magnet DC motor belted to open-style compressor; silver cylinder on the left is a water-cooled condenser.

PINK MOUNTAIN:

19. General view of the site with the 360 Wp array in the yard.
20. Eight identical modules in parallel connection.
21. Array support structure showing manual "turntable" tracker with locking lever.
22. The "bootroom" showing battery storage (636 AH @ 12V), AH meters, two inverters (2000W & 600W), charge regulator, fuse & distribution panels. Note the small vinyl tubes from each cell cap for venting gases.
23. Closer view of the larger 2KW inverter, BOSS regulator, metering, & fusing.
24. Conventional 5 cu ft freezer modified with a 12VDC motor-compressor - not super-insulated.

SMITHERS:

25. General view of the site with 260 Wp array in the yard at right.
26. The array of 4 different modules (all in parallel) slightly elevated on a wooden frame.
27. Pantry/bootroom showing battery storage (430 AH @ 12V) and back-up charger above; on the wall is the charge regulator, fusing, metering, and distribution panel.

HORSEFLY:

28. General view of the site with 188 Wp array mounted under the eave.
29. Array mounting structure and wiring. Identical modules in parallel.
30. Battery room in the house with AH meters (estimated 900 AH @ 12V).
31. Entrance to battery room; on right, inverter shelf and control panel.
32. Left to right - 1.2 KW inverter, charge regulator, low-voltage disconnect, and fuse/switch panel.

CHRISTINA LAKE:

33. General view of the site with 160 Wp array on the porch roof.
34. Simple mounting brackets.
35. Battery storage (216 AH @ 12V) outside under the array with main fuses.
36. Control, metering, and fuse panel with AH meters below.

LASQUETI ISLAND:

37. Overview of the house showing the 2 panel 106 Wp array.
38. Closer view of the unmounted modules.
39. Battery storage (220 AH @ 12V) outside under the eave with a 60 amp back-up charger; on the left, an automotive blocking diode, AH meters, and the fuse/ distribution panel. House is still under construction.

PORT ALICE:

40. The house faces southwest, so the 2 panel 106Wp array is tilted east.
41. Battery storage (240 AH @ 12V) is under the house in an open crawl space.
42. The 200 watt Wincharger "at work" on 26 ft tower.

NELSON ISLAND:

43. The house with 82 Wp array of 2 different panels mounted on gable end.
44. Simple mounting structure is seasonally adjustable.
45. Battery storage (460 AH @ 12V) in unheated closet.
46. Above the batteries are a selector switch, volt & amp meters, and charge regulator; then battery charger, and AH meters.